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THE UNIVERSITY OF ALBERTA

FOREST FIRE HISTORY AROUND JASPER TOWNSITE, JASPER NATIONAL PARK, ALBERTA

by

© GERALD F. TANDE

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

IN

PLANT ECOLOGY

DEPARTMENT OF BOTANY

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This thesis is dedicated to my Parents
and Grandparents for setting the example
and providing The Ethic

ABSTRACT

The objectives of the study were to document the fire history and investigate the role of fire in coniferous forests and woodlands around Jasper townsite, Jasper National Park. Of primary concern was periodicity, location, extent and severity of fires before fire suppression was begun in 1907. Cultural history and past climate were examined in relation to fire regime.

Fire scars were used to establish a fire chronology for the period 1665-1975. A stand origin map was prepared and 45 fire-year maps were constructed. "Major fires" covered more than 1.2% (500 ha) of the area and occurred in 1908, 1906, 1905, 1904, 1889, 1888, 1884, 1883, 1880, 1869, 1863, 1861, 1858, 1847, 1846, 1837, 1834, 1807, 1797, 1780, 1758, 1737, 1727 and 1714. Most of the forested landscape today originated after the fires of 1889, 1847 and 1758.

Mean fire return interval (MFRI) for the 43,200 ha study area between 1665-1975 was 4.4 yrs and 5.5 yrs from 1665-1907. MFRI of major fires was 8.4 yrs. Fires covering more than 50% of the study area had a MFRI of 65.5 yrs. MFRI for 50 ha blocks of lodgepole pine forests was 26.8, Douglas-fir 17.6, grassland-savanna 20.6 and subalpine forests 74 yrs.

A dendroclimatology record was used to assess major drought years or potential fire years. About 70% of the fires and 92% of the total area burned from 1700-1913 occurred during below-mean precipitation periods. The 1758, 1847 and 1889 fires occurred during severe droughts. This and other fire history studies showed many fire years in common, suggesting major atmospheric circulation anomalies

associated with subcontinental drought.

Climate was *the* major environmental factor controlling the frequency and extent of past forest fires. Erratic human-use patterns associated with the study area and good correlations between past climate and fire history suggest that European man should not be blamed for the extensive forest fires of the nineteenth century since he arrived at a time when conditions were more favorable for fire.

Most fires between 1665-1913 were of low to medium intensity but higher intensity ones did occasionally occur. Fires left a heterogeneous age structure on the landscape varying from even-aged stands to a fine-scale patchwork of several age-classes over short distances. Areas containing no evidence of past fires were found at higher elevations, especially on northerly and easterly slopes.

Fire intensity was related to moisture regime, organic matter accumulation, and variations in these factors through plant succession and topographic position. Two major plant/fuel successional sequences were recognized for the study area: high-elevational forests and low-elevational forests.

Weather and climate determine not only the rate of organic matter accumulation, and therefore the amount of fuel, but also whether the fuel at a particular place and time will burn once ignited. Whenever weather conditions were favorable and ignition possible, fires occurred almost as frequently as organic matter accumulated in sufficient quantity to support combustion over the forest floor.

The size of past fires varied non-randomly over time, and was attributed to climatic oscillations and variations of organic matter buildup with time. Integration of the fire history data and plant/fuel

successional sequences indicates that forests of the study area will eventually burn again. Although fire exclusion has not had serious repercussions to date, development of a well-planned program of fire prescription and control is needed to maintain disturbance phases of the forest maturation sequence.

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"Something happens to a man when he sits before a fire. Strange stirrings take place within him and a light comes into his eyes that was not there before..."

"There have been countless (fires), each one different, but some so blended into their backgrounds that it is hard for them to emerge. But I have found that when I catch even a glimmer of their almost forgotten light..., they begin to flame once more. Those old fires have strange and wonderful powers..."

"Campfires" by Sigurd F. Olson in The Singing Wilderness (illustrated by Francis Lee Jacques, copyright 1956, Alfred E. Knopf, Inc.)

As my good friend Tom Lee once said, "Forward, into the Past"

INTRODUCTION

The maintenance and survival of many plant communities and ecosystems depends upon the frequent occurrence of fire. Fire is the key environmental factor that initiates secondary successions, controls the species composition and age structure of these plant communities, and thereby produces the vegetation patterns upon which the consumer components of the ecosystem depend (Wright and Heinselman 1973).

Evolutionary response to fire can be seen in the many reproductive and vegetative adaptations which species have developed in order to survive periodic burning. Examples include underground rhizomes; root sprouting; light-weight winged seeds; serotinous cones; and thick, corky, fire-resistant bark. Some species also store energy in bulbs and corms to replace foliage destroyed by a burn. Fire may produce a nutrient-rich seed bed, relatively high light intensities at ground level, and lower competitive stresses, thereby encouraging germination and establishment of certain fire-dependent tree species. Discussion of these adaptations can be found in Clements (1910), Ahlgren and Ahlgren (1960), Lotan (1976) and Lyon and Stickney (1976). Mutch (1970) hypothesized that many fire-adapted communities have a considerable number of plant species with characteristics that enhance flammability, thus predisposing the community to fire. Fire can thus be considered an important natural disturbance factor that has influenced plant communities over evolutionary time.

Many of these fire-dependent communities are prominent components of the vegetation of North America and the world. Only

temperate and tropical rain forests escape the regular occurrence of fire. Most boreal, grassland, pine, eucalypt and oak communities of the world are fire dependent (Kozlowski and Ahlgren 1975).

The importance of fire in North American vegetation types has been described by many authors: grasslands (Daubenmire 1968a, Vogl 1974); chaparral (Biswell 1974); desert and desert grassland (Humphrey 1974); southeastern coniferous forests (Komarek 1974); northern coniferous forests in general (Wright and Heinselman 1973); northcentral forests (Heinselman 1970, Frissell 1973, Heinselman 1973, Ahlgren 1974); western coniferous forests (Cooper 1961, Weaver 1974); northern Rocky Mountains (Habeck and Mutch 1973, Loope and Gruell 1973); Sierra Nevada (Kilgore 1973); and boreal forest (Lutz 1956, Rowe and Scotter 1973, Viereck 1973, Rowe *et al.* 1974, 1975).

The importance of fire in the environment remains the subject of much investigation. Some of the more often mentioned roles have been summarized by Wright and Heinselman (1973) as follows:

1) Modifier of the physical-chemical environment,
2) Regulator of dry matter accumulation,
3) Controller of plant species composition and structure of plant communities,
4) Determiner of wildlife habitat patterns and populations,
5) Controller of forest insects, parasites and fungi,
6) Controller of major ecosystem processes and characteristics.

An important aspect of all fire-dependent communities and ecosystems that integrates these factors is the "fire regime" (Heinselman 1975), which consists of the following:

1) Average number of years between fire years (mean return

interval) for vegetation types and physiographic site types,

2) Maximum and minimum fire return intervals for vegetation types and physiographic site types,

3) Characteristic fire intensity and behavior,

4) Characteristic fire size (if variable, then typical maximum and minimum areas),

5) Interactions between climatic variations and fire occurrence,

6) Relationship between fire and cultural history of the area.

Natural fire regimes for many plant communities and ecosystems are not known. However, fire history studies have appeared in recent years for different conifer forest regions of North America. Fire in the boreal forest of western Canada has been documented by Rowe *et al.* (1974, 1975) and Johnson and Rowe (1975). Fire-scar studies and palynology were used in a fire history investigation of the Algonquin Provincial Park region, Ontario (Cwynar 1975). Heinselman (1973) described the fire ecology of the contemporary vegetation of northeastern Minnesota with a detailed account of the tree-ring record. Frissell (1973) studied a much smaller remnant of virgin forest in north central Minnesota. Swain (1973) used charcoal and pollen stratigraphy to show that fire has been an important ecological factor throughout the post-Wisconsin forest history of northern Minnesota.

In the western United States, Sierran conifer forests have been studied by Kilgore (1973) and McBride and Laven (1976). Johnson and Smathers (1976) conducted a fire ecology investigation for Lava Beds National Monument in northern California. Natural fire regimes in Oregon have been described by Weaver (1959) and Soeriaatmadja (1966). Martin *et al.* (1976) have hypothesized fire frequencies for various

vegetation types in the Pacific northwest. The role of fire in a portion of the Cascade Mountains of Washington State has been examined by Fahnestock (1976), and fire history studies have recently been used to assess the causes of juniper invasion in southwestern Idaho (Burkhardt and Tisdale 1976).

Tree-ring analyses of fire history in the Rocky Mountains began with Clements (1910) who first outlined the basic techniques of fire-scar analysis in his study of fire and lodgepole pine (*Pinus contorta* var. *latifolia*)* succession around Estes Park, Colorado. A fire ecology study has since been carried out in the subalpine forests of Rocky Mountain National Park (Clagg 1975). Loope and Gruell (1973) examined the historical importance of fire in the Jackson Hole area of northwestern Wyoming, while Horton (1973) studied fire frequency in the Douglas-fir (*Pseudotsuga menziesii*) savannas of northern Yellowstone National Park. Habeck (1972) reviewed the fire history and ecology of the Selway-Bitterroot Wilderness of Idaho and Montana. More recently, Gabriel (1976) documented the role of fire in the Danaher Drainage of the Bob Marshall Wilderness Area, Montana, and Arno (1976) has completed a four century fire history of the Bitterroot Mountains.

The few fire history investigations carried out in the Canadian Rocky Mountains have relied on information other than the fire-scar record. MacKenzie (1973) used age data to construct crude dates of origin for the forests of Waterton Lakes National Park. Byrne (1968) relied completely on historical and scientific literature to describe man and landscape change in Banff National Park before 1910. Neither investigator recognized the potential of constructing a detailed fire history by sectioning fire-scarred trees.

---

*nomenclature follows Moss 1959.

Beil (1966), Stringer (1966), Hnatiuk (1969), Laidlaw (1971), Stringer (1973), Lee (1976) and Lulman (1976) agreed that fire played an important role in many of the vegetation types of Banff and Jasper National Parks, including the Athabasca, Miette and Maligne River valleys around Jasper townsite. Hettinger (1975) believed that fire frequency was related to the complex pattern of montane community types and successional rates of different community types in the Vine Creek drainage basin of the Athabasca River valley. In 1975, Heinselman concluded that the Athabasca River valley around Jasper townsite was a fire-dependent ecosystem.

Objectives of the Study

The ecological importance of fire in the Canadian Rocky Mountains has long been recognized but natural fire regimes have not been investigated in detail. This fact prompted the initiation of this project in 1974. The major objectives were to document the fire history, and investigate the role of fire in shaping the vegetation of the Athabasca, Miette and Maligne River valleys around Jasper townsite, Jasper National Park. Specific considerations were as follows:

A. To document the natural fire regime before active fire control was established in 1907. This involved determination of

   1. The periodicity of fire occurrence in the study area,
   2. The location and areal extent of fires,
   3. The intensity of fires,
   4. The relationship between fire history and past climate,
   5. The relationship between fire history and cultural history.

B. To use the fire regime as a base for interpreting the influence

of past fires on the vegetation of the study area.

The investigation represents the first attempt to rigorously describe and map the fire history of a forested mountain landscape in the Canadian Rocky Mountains, using current fire history techniques of fire-scar analysis.

DESCRIPTION OF THE STUDY AREA

Location

The study area is located in the Athabasca, Maligne and Miette River valleys around Jasper townsite, Jasper National Park, Alberta, between 52°46' and 53°02' N latitude and 117°55' and 118°14' W longitude (Figure 1). It consists of a 43,200 ha area (slope corrected) of the valleys up to treeline, and extends north down the Athabasca valley to the Snaring River, east up the Maligne valley to Two-Valley Creek, south up the Athabasca to the Astoria River, and west up the Miette valley to Minaga and Meadow Creeks.

Geomorphology

The study area lies in the Main and Front Ranges of the Canadian Rocky Mountains formed during mid-Tertiary times (Stene 1966). Precambrian and Cambrian sedimentary rocks of the Main Ranges are separated from the Devonian and Permian sedimentary rocks of the Front Ranges by the Castle Mountain Thrust Fault, running southeast from the Palisade along the north slope of the Maligne Range (Roed 1968).

The Athabasca River valley was glaciated in the Wisconsin and a preliminary interpretation of the glacial sequence in the Park indicates that the valley east from Jasper townsite was ice-free by 10,500 to 12,000 years B.P. (Stene 1966, Roed 1968, Reeves 1973). Glacial and fluvial processes are primarily responsible for present landforms of the valley floors. The valleys are deep U-shaped troughs paralleling or bisecting numerous steeply uplifted and tilted rock

Figure 1. Location of the study area.

formations. They are mantled with glacial drift consisting of a complex of outwash, morainal debris, river terrace deposits, lake sediments and loess. Such deposits create a series of low ridges, benches and flats above the Athabasca, Maligne and Miette Rivers.

Elevation in the area ranges from 1028 m north of Henry House grassland in the valley, to 2814 m at the summit of Pyramid Mountain. Topographical relief is complex, varying from gentle sloping plateaus and rolling till plains, to steep cliffs and ridges of exposed bedrock. All possible combinations of slope and aspect occur in the valleys as the result of complex drainage patterns and topography (Heinselman 1975), but the prevailing exposures in the main valley are easterly and westerly (Figure 1).

Numerous lakes occur throughout the area. Cabin, Caledonia, Dorothy, Patricia, Saturday Night and the Five Lakes occupy glacially-blocked fluted topography in the Athabasca and Miette River valleys. Other lakes of varying size fill ice-block pits and abandoned river channels, such as in the Lac Beauvert-Edith Lake complex. Hanging wetlands, seeps and fens occur at all elevations, being especially common on the slopes of Signal Mountain and the Palisade.

Soils are usually developed on glacial till, loess and outwash deposits. Parent materials consist primarily of quartzite sandstones and conglomerates (Stringer and LaRoi 1970). Descriptions of soils associated with major vegetation types can be found in Beil (1964), Stringer (1966), Hnatiuk (1969), Stringer (1973) and Lulman (1976).

Climate

Based on temperature and precipitation records, Longley (1970)

has classified the climate of west central Alberta as Sub-Arctic or Cold Snowy Forest. Climatic influences of the Pacific Ocean, however, make winter temperatures somewhat higher in Banff and Jasper than in the rest of this region of the province. In general, the area around Jasper townsite has short, warm summers with high rates of evapotranspiration, and long, cold winters with occasional chinook-like winds that cause marked snow ablation (Stringer and LaRoi 1970).

Regional climatic characteristics in the Park have yet to be accurately determined due to the lack of a comprehensive weather station network (Janz and Storr 1977). Considerable differences in precipitation and temperature may occur over short distances. Mountain ranges near the Continental Divide receive more than 127 cm of precipitation annually, in contrast to the low-lying eastern intermontane valleys which are considerably drier (Laycock 1957). The Athabasca River valley around Jasper townsite is one such valley, and has a drier, warmer climate than either valleys towards the divide or regions outside the Front Ranges. Seasonal total precipitation is lower, and the mean daily temperature for May-September warmer, at Jasper, than anywhere else in west central Alberta (Powell and MacIver 1976).

Jasper townsite has a mean annual precipitation of 40.6 cm, with 28.2 cm falling as rain between the months of April and September (Stringer and LaRoi 1970). June is the wettest month with a mean of 5.46 cm and August the second wettest with 5.11 cm. May and September are the driest months, with values of 3.33 and 3.56 cm respectively (Powell and MacIver 1976). The dry season in May may be accentuated by early loss of snowpack or unusually dry weather in April. The dry season in September may also be accentuated by abnormally low

precipitation in July and August.

Mean annual snowfall is 125 cm or approximately 12 cm water equivalent. In most years snow covers the ground at lower elevations from late October or early November, through late March (Soper 1970). Precipitation increases with elevation and probably exceeds 60 cm above timberline on Pyramid Mountain. A similar trend is expected on other mountains in the vicinity (Lee 1976).

Jasper has a mean annual air temperature of 2.9°C. July is the warmest month with a mean daily maximum of 23.1°C. January is the coldest with a mean daily minimum of -16.8°C (Stringer and LaRoi 1970). Mean temperature decreases with an increase in elevation. Hrapko (1970) has shown that summer diurnal temperature fluctuation is much greater at Jasper townsite than on the summit of Signal Mountain. Higher elevations, therefore, have a cooler, wetter, and perhaps less variable climate than lower elevational areas.

Temperature and precipitation variations from these norms are marked and significant droughts are believed to have occurred in the past (see DISCUSSION: Fire History and Climate).

Air Masses and Storm Tracks

The study area's main climatic features are determined by the western interior location in North America, separation from the Pacific by a series of western mountain barriers, and high elevations. Variation in annual precipitation is dependent upon relative frequency and duration of the influx of maritime polar and maritime tropical air, and the degree to which such air masses are uplifted. Maritime tropical air from the Atlantic and Gulf of Mexico rarely penetrates the Front

Ranges. The most important sources of precipitation are the maritime polar air masses entering the area from the west. Mild and moist on reaching British Columbia, these air masses lose much moisture in crossing the various mountain ranges west of Alberta.

Powell and MacIver (1976) believe that Jasper townsite lies in a marked rain shadow location, since in all summer months it has the lowest precipitation total of any west central Alberta station. Their observation is substantiated by a storm track I frequently witnessed during two field summers in Jasper. Most rainstorms coming across the Continental Divide from the Mt. Robson area appear to leave the Miette River valley near Muhigan Mountain, and travel in a southeasterly direction towards Mt. Kerkeslin (Figure 2). These storms appear to bypass the study area, and deposit their precipitation at higher elevations over the Trident Range and Tonquin Valley. The eastern edge of this storm track follows a line from Marmot to Aquila Mountains, southeast to Athabasca Falls and to Mt. Kerkeslin. Many storms coming down the Miette River valley become somewhat stationary just south of Jasper townsite, before moving slowly up the Athabasca River valley on the flanks of Whistlers and Marmot Mountains.

Tropical continental air occasionally invades the study area in late summer or early fall of some years. These air masses are hot and dry, resulting in temperatures in the range of 28-32°C (Laycock 1957). Such conditions coupled with low relative humidities and low precipitation are especially favorable for forest fires.

Wind

Winds vary in velocity but are strong during most of the year,

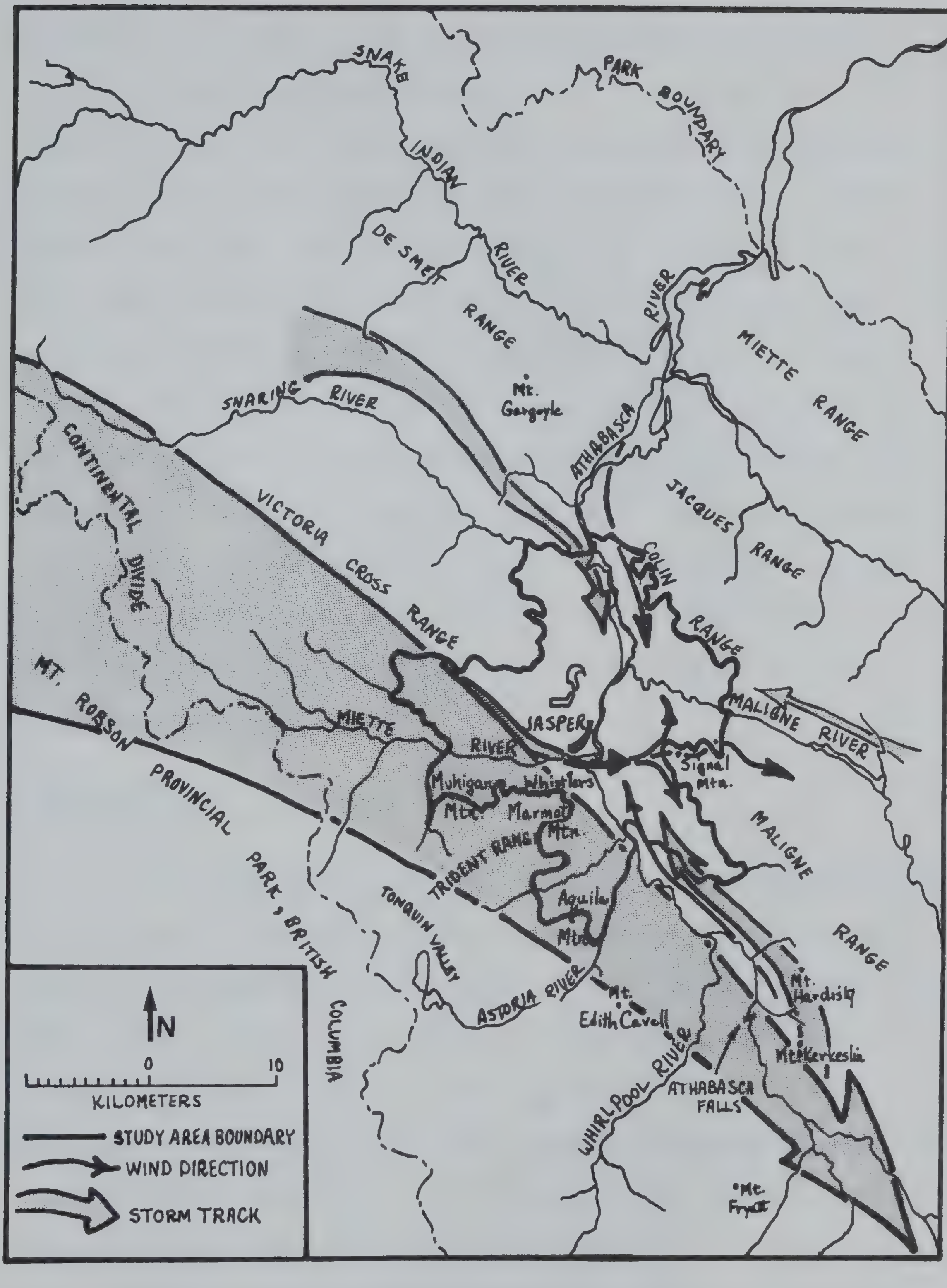


Figure 2. Prevailing wind patterns and storm tracks observed by the author in the vicinity of Jasper townsite.

averaging 12.5 km hr^{-1}. Gale force winds have occasionally been recorded. Wind directions associated with the previously described continental air masses are significantly modified by local topographical features. Prevailing northwesterly winds are funnelled east down the Miette River valley and are then deflected north, northeast, south and over Signal Mountain (Figure 2). These winds are especially common during dry weather. Northwest winds also enter the Athabasca River valley from the Snaring River, but are not common. When they do occur, however, they are usually associated with precipitation (Hrapko 1970). Winds generated in the Columbia Icefields occasionally move north through the study area down the Sunwapta, Whirlpool and Athabasca river valleys. Less frequent are easterly winds moving out of the Maligne River valley. Very complex patterns of wind direction result when two or more of these major paths converge.

Thunderstorms

The frequency of lightning ignition of forest fuels is low in the study area. The average number of lightning fires for the Jasper area is 0.4-2 fires/mil ha/yr or 1-5/mil A/yr (Schroeder and Buck 1970). Simard (1975) indicates that Jasper lies in an area of low fire incidence, experiencing 0.5 fires/mil ha/yr (0.78 fires/mil A/yr). Since his figures include both lightning and man-caused ignitions, the frequency of lightning fires in the Athabasca River valley is probably much lower than that reported by Schroeder and Buck.

Thunderstorm activity increases east and west, towards the foothills and Continental Divide, respectively. Fire records for Jasper National Park since 1946 indicate that the number of reported

fires attributable to lightning is higher in the mountain ranges southwest of Jasper townsite and in the Snake Indian River country, than in the vicinity of the townsite.

Based on statistics for 1962-68, Lawford (1969) has arrived at the following trends for the Jasper vicinity. Late afternoon thunderstorms occur from late May to September and reach a maximum around July 15, but yearly patterns vary greatly. Thunderstorm intensity averaged 20-25 strikes per storm. Less than 2.5% of all storms produce "dry strikes" (lightning originating from clouds which do not produce precipitation at the ground or strikes that occur outside of the rain area).

Vegetation

According to Rowe (1972), the study area lies in the Douglas-fir and Lodgepole Pine Section (M.5) of the Montane Forest Zone, characterized by the association of Douglas-fir and lodgepole pine. As such, it represents the northern-most element of the section in the eastern Rocky Mountains. Based upon vegetation and floristics, the study area lies near the boundary of Daubenmire's (1943) Northern and Far Northern Rocky Mountain regions. Three major elevational zones have been recognized in the park: the montane and subalpine, which this study encompasses; and the alpine (Oosting 1956, Rowe 1972). These categories have been further subdivided by LaRoi (1975).

The montane zone extends from the valley bottom to the upper limit of intermittent winter snow cover (LaRoi 1975) at about 1530 m (Lee 1976). Within this zone, seven generalized community types have been recognized in this study: Douglas-fir, lodgepole pine, white

spruce (*Picea glauca*), black spruce (*P. mariana*), trembling aspen (*Populus tremuloides*), and balsam poplar (*P. balsamifera*) forest, grassland-savanna, and rock outcrops. Engelmann spruce-subalpine fir (*Picea engelmannii-Abies lasiocarpa*) type inhabits much of the subalpine zone, which extends from the upper limit of the montane zone (1530 m) to the upper tree line (2040 m).

Montane Douglas-fir Forest. Douglas-fir has been widely used to characterize and delimit the montane zone in the Canadian Rocky Mountains (Stringer and LaRoi 1970, Rowe 1972). In the Athabasca River valley this type occupies warm, dry till benches, slopes and flats on south and west aspects (Stringer 1966). Douglas-fir occurs as scattered individuals of variable age in open and closed stands of lodgepole pine and sometimes with white spruce, trembling aspen or balsam poplar up to about 1860 m. Pure climax stands can be found throughout the study area, especially in the vicinity of the townsite. Douglas-fir savanna occurs where stands of Douglas-fir adjoin grassland in the flat dry valley bottom.

Montane Lodgepole Pine Forest. These forests and woodlands constitute the most extensive forest type of the slopes and valleys of the study area. This cover type is common at higher elevations as well, where fire has occurred in the subalpine zone. Relatively pure and nearly even-aged stands of dense pine occur on many sites, although some stands at lower elevations have two or more age classes, reflecting the complex fire history. Hnatiuk (1969) has made a detailed synecological study of the lodgepole pine community types of Banff and Jasper National Parks.

Montane White Spruce Forest. The climax counterpart of Douglas-fir on more mesic sites is white spruce (LaRoi 1975). This type is found on young river terraces, ravine bottoms and streamsides, river banks and north facing slopes (Stringer and LaRoi 1970). Pure stands of white spruce are uncommon in the study area, except on alluvial flats adjoining the Athabasca River. Scattered individuals are associated with lodgepole pine, black spruce, trembling aspen and balsam poplar throughout the area. Hybridization with Engelmann spruce occurs with increasing elevation (Beil 1966, LaRoi and Dugle 1968).

Montane Black Spruce Forest. Black spruce is a minor component of the forest vegetation of the valley. It is, however, the dominant tree on wooded lake margins, seeps, fens and peatlands (Laidlaw 1971). It also occurs on old alluvium of stream courses and at higher elevations in hanging wetlands (Hettinger 1975) and in wet-mesic lodgepole pine and Engelmann spruce-subalpine fir communities.

Montane Trembling Aspen and Balsam Poplar Forest. Trembling aspen and balsam poplar form small stands in the study area. Pure-canopy stands of trembling aspen are common on large fan-shaped scree slopes, avalanche paths, alluvial fans, river terraces and glacial till deposits (Lulman 1976). They generally contrast sharply with surrounding evergreen forests. Balsam poplar is more restricted than trembling aspen and is found on coarse alluvium associated with depositional disturbance sites such as river meanders (Hettinger 1975).

Montane Grassland-Savanna. This vegetation type is found sporadically on warm, dry valley flats, south and west-facing slopes of valley benches, exposed ridges and old beaver-meadow complexes.

Lodgepole pine, Douglas-fir, white spruce and trembling aspen are the typical savanna tree species associated with the xerophytic *Koeleria cristata-Calamagrostis montanensis* grassland (Stringer 1973).

Subalpine Engelmann Spruce-Subalpine Fir Forest. A mesic climax Engelmann spruce-subalpine fir forest is the dominant cover type of the subalpine zone, although open woodland, treeless scrub, bog and fen communities are also present (LaRoi 1975). Even-aged, post-fire forests of lodgepole pine cover much of the subalpine, especially on south-and west-facing slopes. Other minor but constant species found in the subalpine are black spruce at the lower limits of the zone, and white bark pine (*Pinus albicaulis*) on exposed ridges (Beil 1966). Engelmann spruce and black spruce fens are common on wetter sites.

Rock Outcrop. These xeric communities are found throughout the montane and subalpine zones. Total plant cover is minimal. The bryophyte and vascular plant assemblages of several rock outcrops in the study area have been described by Lee (1976).

Plant Succession

Four major upland forest "habitat types" (Daubenmire 1968b) occur in the study area around Jasper townsite. In the montane zone, succession proceeds towards Douglas-fir on warm dry-mesic sites and to white spruce on cool moist sites (Stringer and LaRoi 1970). Lulman (1976) considers trembling aspen to be subclimax to white spruce on mesic sites, and to lodgepole pine and Douglas-fir on more xeric sites. On the mesic end of a moisture gradient, Hnatiuk (1969) found lodgepole pine to be rapidly succeeding to a spruce-fir forest. However, on the

xeric end, he found succession towards spruce fir or Douglas-fir to be very slow and uncertain. He concluded that a lodgepole pine physiographic climax exists on some xeric sites.

Succession in the subalpine zone is towards a subalpine fir-Engelmann spruce climax (Beil 1966). Day (1972) has described a successional sequence for the subalpine forests of the Crowsnest area that may be applicable to both boreal and Cordillerean spruce species in the Jasper area. He recognized four phases in the post-fire succession behavior of mixed lodgepole pine-spruce-fir forests which provide a rough scale on the rate of succession from pine to fir and white and Engelmann spruce intermediates.

<u>Phase 1</u> (55 yrs after fire) occurs during the period of dominance by a dense, even-aged lodgepole pine overstory. Invasion by spruce and fir is occurring, but only spruce has attained much prominence.

<u>Phase 2</u> (155 yrs after fire) is evident when spruce is beginning to dominate over pine, and fir is aggressively invading.

<u>Phase 3</u> (255 yrs after fire) occurs when pine is decadent or dying, and spruce is dominating. In the understory, fir is now three times as numerous as spruce.

<u>Phase 4</u> (355 yrs after fire) is found when all of the original post-fire pine and spruce are dead, and replaced by an uneven, understocked stand of fir and some spruce, with an uneven to all-aged stand structure.

Cultural History

The intention of this section is to provide an overview of the

study area's cultural history and acquaint the reader with the increased human activity through time.

Jasper's past can be divided into six major cultural periods (Table 1). These divisions are arbitrary, but the different cultural values and activities they represent are clearly differentiated as will be shown in the sections to follow. The importance of man as a cause of forest fires will be discussed in the concluding section.

The Pre-European Period (*ca.* 10,000 B.P.-*ca.* 1800). This period is dominated by the activities of native peoples. Acculturation by the white man was not completed until the late eighteenth century and therefore the activities of these peoples somewhat overlaps the Fur Trade and Presettlement Periods.

Little information exists on the history of the Athabasca River valley before 1811. Anderson and Reeves (1975) conducted a preliminary archeological survey based on interpretations of projectile points and associated lithics. The following paragraphs summarize their findings.

The Athabasca River valley was used by native people since the retreat of the Athabasca River valley glacier from the present Jasper townsite 10,000 B.P. The earliest people were culturally related to Northern Plains and Rocky Mountain groups. They moved into the valley as far as Jasper Lake from the eastern foothills by 7500 B.P. These people remained in the vicinity through a period of milder weather called the Altithermal which lasted until *ca.* 5000 B.P.

Northern Boreal/Cordilleran people moved into the region as the result of neoglaciations after the Altithermal. Projectile point distribution suggests that these people were wide-ranging and indigenous

TABLE 1. The six major cultural periods for the Athabasca River valley around Jasper townsite, Jasper National Park.

1.	The Pre-European Period	(*ca.* 10,000 B.P. - *ca.* 1800)
2.	The Fur Trade Period	(*ca.* 1800 - *ca.* 1830)
3.	The Presettlement Period	(*ca.* 1830 - 1892)
4.	The Settlement Period	(1892 - 1910)
5.	The Railroad Period	(1909 - 1912)
6.	The Park Period	(1913 - 1975)

to the Rocky Mountains. Although contacts were made with the Northern Plains and Rocky Mountain peoples, the Northern Boreal/ Cordilleran populations remained dominant until acculturation during the fur trade. Native Indian groups of the Jasper area included the Shuswap, Stoney, Iroquois, Cree, Metis and various Athapascan linquistic groups (Sekani, Beaver and Sarci).

The Athapascans were probably the native people of the area prior to the fur trade. They were nomadic, consisting of small wandering groups who subsisted by hunting small populations of ungulates. Fishing, snaring of small mammals, and seasonal gathering of berries and plants supplemented the ungulate diet. Bands of the Beaver group inhabited the area north of the Miette and Athabasca Rivers, and those of the Sarci south of the Athabasca along the Front Ranges. The Sekani groups occupied country east of the Continental Divide and south and west of the Beaver. The Cree and Beaver eventually pushed the Sekani groups west of the divide where the Shuswap forced them still further north.

Shortly before 1800, the Stoneys reached the foothills between the Athabasca and North Saskatchewan Rivers as the result of westward expansion of Cree territory and the fur trade. They traded at the Jasper Houses between 1824 and 1834. A small Stoney group of about 50 lodges called Peoples of the Forest ranged through the upper Athabasca and North Saskatchewan River systems in 1840-50. However, game became scarce by the late 1840's forcing them to move further south along the Front Ranges in search of better hunting grounds.

The Shuswap of British Columbia were displaced north and west of the Columbia Lakes region by the Kootenai moving westward across the

mountains from their traditional east slope land. By the 1830's, the Rocky Mountain Shuswap had a territory covering the intermontane from the headwaters of the Thompson and Fraser Rivers to the Yellowhead, Athabasca and Smoky River valleys (Teit 1909). These far-ranging nomadic people lived in small bands and subsisted on a wide range of food sources from wild ungulates and small mammals, to waterfowl and fish.

Because of continual contact with the fur trade posts in the Athabasca River valley, the Rocky Mountain Shuswap intermarried with the Iroquois, Cree and Metis (Teit 1909). These three groups were inextricably associated with the fur trade in the Jasper Park region. Iroquois freemen and hunters are mentioned many times in old records (Coues 1897, Cox 1830). Less nomadic than earlier groups, they hunted and trapped in the Athabasca, Yellowhead, and upper Fraser River valleys prior to the establishment of the first Jasper House in 1813. Some Metis families, such as the Moberleys, settled in the Athabasca valley prior to the establishment of the park.

To summarize, the native peoples of the Jasper Park region moved into the area accompanying the fur traders (*e.g.* Iroquois, Metis) or by moving in front of them (Cree and Stoney). These latter groups displaced the Athapascans and, by a domino effect, the Shuswap, from their traditional lands in British Columbia. They were all nomadic hunters who travelled in family size groups and subsisted on small populations of game animals in a harsh mountain environment. On the basis of these observations, population density of the early inhabitants was probably never high.

<u>The Fur Trade Period (*ca.* 1800-*ca.* 1830)</u>. The history of Jasper from 1800 to 1830 largely centred on the Athabasca River valley's role during the fur trade era. Incomplete historical records show that Iroquois freemen pushed into the mountains in search of furs and major passes over the mountains between 1770 and 1802 (MacGregor 1974). Though he never set foot in the Rocky Mountains himself, Peter Pond first depicted the "Great River Araubaska" rising in the mountains and flowing northeast (Soper 1970).

History begins in the valley with David Thompson's crossing of the Athabasca Pass in 1810-11. On January 6, 1811, he left for the pass leaving William Henry behind to establish a winter camp on the east side of the Athabasca River opposite the mouth of Miette River (Anderson and Reeves 1975). Thompson's brigade returned to the camp in May, 1811 and again in October, 1812, when they found that Henry had moved camp to the vicinity of the south shore of Lac Beavert on the east bank of the Athabasca River to what is now called the first Henry House (MacGregor 1974).

Activity in the valley increased in 1813 when the Northwest Company constructed Rocky Mountain House on the northeast end of Brulé Lake. Sometime later, Jasper Hawse took charge (Soper 1970) and the post become known as the first Jasper House. It became a supply depot for fur brigades and a seasonal trading post for the native people. The Fur Trade Route thus began with the establishment of this post and Thompson's last crossing of the Athabasca Pass. Regular brigades of the Northwest Company passed from Ft. Edmonton on the North Saskatchewan overland to Ft. Assiniboine and up the Athabasca by canoe to Jasper House. They proceeded on horseback to Henry House and the Prairie de la

Vache in the study area, where they began the difficult walk up the Whirlpool to the Athabasca Pass and the Columbia River system beyond.

As early as 1820, the practice was to bring a fur brigade to Jasper House and disperse in all directions in search of furs (Anderson 1973). No information exists on the numbers of trappers this involved. However, the entire Jasper region was probably penetrated by native or white trappers by the peak of the Fur Trade Period.

Fur trade activity probably peaked in the Athabasca River valley between 1820 and 1830. The Northwest Company was amalgomated with the Hudson's Bay Company in 1821 (Anderson and Reeves 1975). By the time Michael Klyne (Clyne) took over as chief factor of Jasper House in 1825, the fur trade had begun to deteriorate (Anderson 1973).

The erratic opening and closing of various posts reflected the waning fur trade and activity in the valley. In 1829, the Hudson's Bay Company built a post opposite the first Henry House that was variously known as the second Henry House, Laroque's House, or Miette's House (Anderson and Reeves 1975). It was officially discontinued in 1830 and abandoned in 1835. The first Jasper House was also abandoned in 1829 and a second constructed at the north end of Jasper Lake. By the 1840's, fur trade activity in the Jasper Park region had declined to the point that Jasper House was operated only sporadically. It served as a seasonal trading centre until it was finally abandoned in 1884.

The Presettlement Period (*ca.* 1830-1892). The Jasper area continued to be used as the Fur Trade Period faded. Travellers as well as the fur trappers and explorers utilized the Athabasca and Yellowhead routes to cross the Rocky Mountains shortly after the merging of the

Northwest and Hudson's Bay Companies (Cox 1830, Drummond 1830, Coues 1897, Douglas 1914). Their accounts describe travel through the valley but say very little concerning human activity in the area. Colin Fraser, a factor of Jasper House, did record the travel of Fs. Blanchet and Demera through the valley in 1835 when they baptized 35 Metis children in one day. This indicates that the population of the Athabasca River valley, at least in the vicinity of the post, was denser than some other accounts suggest.

Only a few documents record travel through the valley from 1840 to 1859. In the spring of 1846, Father DeSmet spent a month in the valley at Jasper House on his way west (Chittenden and Richardson 1905). The artist Paul Kane, arrived at the post in the fall of that year, crossing the Athabasca Pass and returning in 1847 (Kane 1859).

The Caribou gold rush drew larger concentrations of people through the area as early as 1860. The largest single party to pass this way was the Overlanders of 1862, numbering about 150 men, women and children (Soper 1970). In 1863, Milton and Cheadle entered the mountains, travelled to Jasper House and made their way through the Yellowhead Pass on their way to the west coast (Cheadle 1971).

Exploration and development of the mountain passes further south led to a gradual decline in the use of the Athabasca and Yellowhead Passes. The latter was surveyed by Walter Moberley and Morius Smith in 1871-72 for the Canadian Pacific Railroad. However, no written accounts could be found for the period 1872-1891. This suggests that human activity in the valleys had drastically declined from the heavy use associated with the Fur Trade Period.

In summary, many people passed through the study area during

the Presettlement Period, especially during the first 35 years, but few stayed for any length of time. Accounts suggest that there were very few, if any, inhabitants of the area. Continuous activity occurred in the valley, although it was probably less pronounced than during the fur trade.

The Settlement Period (1892-1910). Attempts were made to settle in the area after the abandonment of Jasper House. Lewis J. Swift entered the valley in 1892 and briefly occupied the old post before moving to the Palisade in 1894 and filing for a homestead. After a brief absence, he returned and settled in the valley in 1897. Squatters occupied various tracts of land in the area as well, and numbered about 100 in 1907 when Jasper National Park was established (Coleman 1911). By 1910, all had been evicted from the Park except Swift who maintained a legal homestead.

The area was also visited by mountain climbers, explorers and scientists between 1890 and 1910. A.P. Coleman attempted to get to the Athabasca Pass peaks as early as 1894 and in 1907 his party passed through the study area on the way to Mt. Robson. Mary Schäeffer stayed at the Swift ranch the same year after her rediscovery of Maligne Lake (Schäeffer 1911).

The first scientific expedition to the Jasper Park region since Douglas in 1827 was made by J. Alden Loring of the United States Biological Survey in 1895-97. The Canadian naturalist William Spreadborough, collected for the Natural History Section of the Geological Survey of Canada in 1898 (Soper 1970). Activity in the Athabasca River valley therefore remained minimal during the Settlement Period, except for these brief forays through the area and the localized

activities of the settlers.

The Railroad Period (1909-1912). The early Park had little, if any, increase in human activity during its first few years. However, the population of the Athabasca River valley swelled with the beginning of the Railroad Period in 1909. Four thousand people were associated with the building of a tote road south from Entrance outside the park and west up the Miette River to the Yellowhead Pass ahead of the Grand Trunk Pacific Railroad (GTPRR). Towns such as Pocohontas flourished because of the coal mine operations (Anderson 1973). In 1911, the town of Fitzhugh was established as a construction camp, then the name was changed to Jasper townsite when the plateau between the Miette and Athabasca Rivers was cleared in 1912. The GTPRR reached the Yellowhead this same year and a regular railroad service to Jasper was established.

The Park Period (1913-1975). The commissioner of Jasper National Park carried out his duties from Edmonton during the park's first few years of operation. The first chief forest ranger was not appointed until 1909 when poaching and the hazard of forest fires increased with the advent of the Railroad Period. He and two game wardens were responsible for all 12,950 km^2 of the original park. The park's size was consequently reduced in 1910 to 25.9 km^2 either side of the railroad right-of-way (Anderson 1973).

Jasper received its first full-time superintendent in 1913. The railroad, recognizing the park's potential, lobbied for expansion of the Park's boundaries to its original size. In 1914, Jasper Park was enlarged to its present size of 11,396 km^2, and expansion of the park's facilities followed.

An all-weather road between Jasper and Edmonton was completed in 1928 and the Yellowhead Highway gravelled to the British Columbia boundary by 1937. The Jasper-Banff Highway was completed in 1939. All highways were paved by 1970 (Anderson 1973). Tourist facilities were built and human activity rapidly intensified to its present state. As in the Fur Trade and Presettlement Periods, the majority of park visitors are simply passing through the area. Today, the study area lies astride the Canadian National Railway, Yellowhead Highway and the Transmountain Pipeline, and is thus a major transportation and communications corridor as well as a recreation centre. In 1974/75, 1,709,770 people visited or passed through Jasper National Park (Parks Canada 1975).

The increase in railroad and human activity throughout this period led to the need for more intensive fire protection. As a result, fire control was begun shortly after the park was established in 1907. Early control efforts were hampered by the lack of fire lookouts, manpower, and access within the Park. The study area has had good control since 1910 because the townsite and railroad were located within it. Fire control for the rest of Jasper National Park was not effective until the late 1940's when a system of lookouts, an adequate warden force, and an effective trail system were available (Mac Elder pers. comm. 1974).

METHODS

General Sampling Procedure

Preliminary Analysis of the Study Area. The study area was delineated on 1972 airphotos (series A23015; scale 1 cm = 740 m) in the laboratory prior to actual field work. Acetate overlays of the vegetation patterns were prepared on enlargements of the original airphotos, and both were carried in the field.

All vegetation patterning differentiated by changes in color or texture was outlined because no previous field work had been completed to establish what constituted fire margins on airphotos. The following were noted for field investigation: (1) possible fire margins; (2) remnant stands of forest; and (3) other areas potentially harboring fire information such as stream sides, wetlands, cliffs and open-grown forests of Douglas-fir. Based on these interpretations, a tentative sampling procedure was established for field trial with the following objectives: (1) visiting elements of the vegetation mosaic; (2) analyzing age structures; and (3) verifying with fire evidence.

Field Reconaissance. Six days were allotted for a field reconaissance of the study area. The purposes of the reconaissance were: (1) to get a general feeling for the size, accessibility and complexity of the area; (2) to ground-truth portions of the vegetation mosaic and obtain evidence of the role of fire in creating the mosaic; and (3) to implement and test the tentative sampling procedure and equipment based on the above considerations.

Scenic overlooks were visited to see if the vegetation patterning found in the airphoto analysis could be recognized in the field. Ground-truthing was accomplished by visiting large segments of the study area on foot. Actual fire boundaries were located at this time and characterized. Potential natural fire boundaries such as rivers and wetlands were investigated to assess conformity to actual boundaries and usefulness to the study. Vegetation mosaic margins were visited to see if the boundaries were the result of fire or due to physiographic factors, or both. The presence of fire-scarred trees, fallen or standing fire-killed snags and changes in the size and age class composition of various lodgepole pine stands indicated the presence of a fire margin.

Results of the field reconaissance indicated that the tentative sampling procedures were unacceptable. An alternative sampling procedure was decided upon for the following reasons:

1) Many parts of the vegetation mosaic identified on 1972 airphotos were difficult to locate on the ground in 1974.
2) Old fire margins were indistinct over most of the area because they had been erased by subsequent fires or had otherwise become obscured since the last major fire.
3) Ruggedness of the terrain limited accessibility to portions of the large study area.
4) The time necessary to overcome the above problems imposed limits on the amount of data that could be collected in one field season.

Sampling Procedure, Summer 1974. The study area was divided into units that could be covered in one day. Based upon the field

reconaissance, an average of 24 km of foot travel could be covered by a field team collecting 20-40 increment cores, fire scars and other pertinent field information in a normal 9.5 hour working day. Fifty-two manageable study units were established within the area using natural and manmade boundaries such as rivers, streams, wetlands, ridgelines, roads and trails.

Once a study unit was established, its vegetation patterns were ascertained with a stereoscope. One sample point was centrally located within each of the 10 major discernable stands within a study unit.

Stands were systematically studied while walking between the sample points. Data was recorded enroute concerning changes in tree species composition, different size classes of trees, and remnant stands of lodgepole pine that had survived previous fires. Evidence suggesting past fires such as fire-scarred trees, charred stumps and standing and fallen snags was noted. Occasional fire scars were collected to document fire dates.

Stands were located with the use of airphotos, topographic maps, landform features and surrounding landmarks. In each stand the date of origin of all components was determined by taking 2-4 increment cores from dominant, codominant and suppressed lodgepole pine with a Swedish increment borer (0.4 cm DIAM). Size classes of the tree stratum were used to estimate the age structure of the stand. All trees were bored 25 cm above ground. To avoid breakage, specimens were stored in a 21 x 35 cm grooved wooden block after removal from a tree. Larger cores were stored in numbered plastic soda straws and a larger cardboard tube for transportion in the field. Diameters of the bored

trees were measured in centimeters 1.4 m above ground with a diameter tape. Heights of the trees were measured in meters with a Suunto clinometer. Fire sign was noted and an occasional fire scar removed with a bow saw from fire-scarred trees to document past fires. A soil pit was dug to check for the occurrence of a charcoal layer.

Data on community structure and composition and physical site characteristics were collected at each site. This information does not appear in this thesis but will be analyzed at a later date for relationships between stand age and stand composition.

A circular plot 20 m in diameter was established with the plot centre located 10 m in a random direction from the first cored tree. Percent total cover of trees, shrubs, herb-dwarf shrubs, mosses, lichens, deadwood and bare ground were estimated. All species present in the plot were listed, and unidentified specimens were collected for later identification. The following Zürich-Montpellier (Z-M) cover scale was used within the plot:

R = rare	4 = 26-50%
+ = common, less than 1%	5 = 51-75%
1 = abundant, 1-5%	6 = 76-95%
2 = 6-15%	7 = 96-100%.
3 = 16-25%	

Physical site characteristics were also noted. Elevation of the site was determined with a pocket altimeter. The slope angle of the sample plot was measured with a Suunto clinometer. Aspect of the plot was recorded using the compass. Moisture regime of the site was subjectively estimated to be xeric, dry mesic, mesic, wet mesic or hydric.

Additional notes were taken on the surrounding vegetation and general topography, dead-fall accumulation, activities of animals and man, and presence of dwarf mistletoe (*Arceuthobium americanum*). Photographs of the site were taken for future reference.

The fire scar and stand origin data of the 1974 field season were used to prepare preliminary stand origin and fire year maps (Tande 1975).

Sampling Procedure, Summer 1975. Field work was carried out during part of a second field season for the following reasons:

1) A preliminary analysis of the stand origin data revealed that exact fire years could not be obtained from tree age data alone.
2) The full value of fire scars for determination of burn dates was not recognized until late in the first field season. Time did not allow a return to areas visited early in the first field season to collect necessary scars.
3) Tentative major breaks in mapped stand origin dates did not reveal distinct fire margins on airphotos. Fire intensity was not understood at this stage of the study.

Further research during the summer of 1975 was therefore undertaken to validate burn margins, extend the fire chronology, and clarify other matters relating to the objectives of the study.

Dr. Miron L. Heinselman, fire ecologist from the University of Minnesota, spent June 8-14, 1975 in the study area. His comments, suggestions and advice concerning fire history techniques were incorporated into the present study and are outlined below (Heinselman 1975).

Questionable areas determined from the first summer's data were revisited. Data collected followed that of the first summer. However, emphasis was placed on collecting fire scars and increment cores from older and larger lodgepole pine than previously sampled. In addition, sections were removed from two large Douglas-fir in an attempt to extend the chronology past the maximum age attained by lodgepole pine.

Description of Fire History Techniques

Fire history techniques were first outlined by Clements (1910) and elaborated on by Spurr (1954), Frissell (1973) and Heinselman (1973). The methods used in this study are discussed in detail because only little information exists in the literature concerning the details of such investigations (Arno 1976, McBride and Laven 1976).

Forest fire sign such as standing or fallen fire-killed snags and stumps, and charcoal in the soil serve to indicate past forest fires but do not provide the investigator with the actual date of the disturbance. Severe fires may kill all elements of a forest or leave scattered individuals or remnant stands. These survivors and standing fire-killed snags serve as seed sources for the new forest. The uniform age of the new stand that occupies the site provides an approximate date of the last major fire. If the fire was not severe enough to kill all elements of the original forest, some individuals may have survived with fire-scarred trunks (Figure 3). When occasional scars are formed at the base of a tree, new wood subsequently grows from the still living edge of the cambium layer toward the centre of the wound. By counting the rings to the points were the calluses occur, it is possible to accurately determine the dates when the various fires occurred.

Figure 3. Fire-scarred lodgepole pine tree. Note the exposed, triangular-shaped, dry yellow sapwood that extends from the soil surface up the trunk of the tree for some distance.

Thus, fire scars constitute the most important and reliable information in fire history studies. They not only provide the evidence for past fires, but also confirm the age class record of the elements of a forest mosaic. At the same time, the initial scar may indicate burn direction and the presence of a burn margin. If the section is cut deep enough, the date of origin of the former stand can be approximated and hidden fire scars revealed, when present.

Fire scars were collected from lodgepole pine because they were prevalent in the study area, easy to obtain, and possessed distinct annual rings (Figure 4). Douglas-fir was used less frequently because of its local distribution, difficulties encountered in sectioning large trees, and variations in ring counts when compared with known burns of an area (Figure 5). Occasional burn dates were obtained from wedges or sections removed from standing or wind-felled snags (Figure 6), and some from cores taken with a Swedish increment borer.

Increment cores obtained from lodgepole pine and periodically from black spruce, white spruce, Engelmann spruce, subalpine fir, Douglas-fir and trembling aspen were used to establish stand origin dates. Age data was used to determine the areal extent of past fires. The scar dates were used to establish the fire chronology and verify stand origin dates whenever possible.

Formation of Fire Scars. Various factors such as fire intensity, resin content, structure and relative thickness of the bark influence the initial fire scar formation. Lodgepole pine, black spruce, white spruce, Engelmann spruce, trembling aspen and balsam poplar are all highly susceptible to destruction by fire. Young trembling aspen is easily destroyed because of its paper-thin bark. Balsam poplar

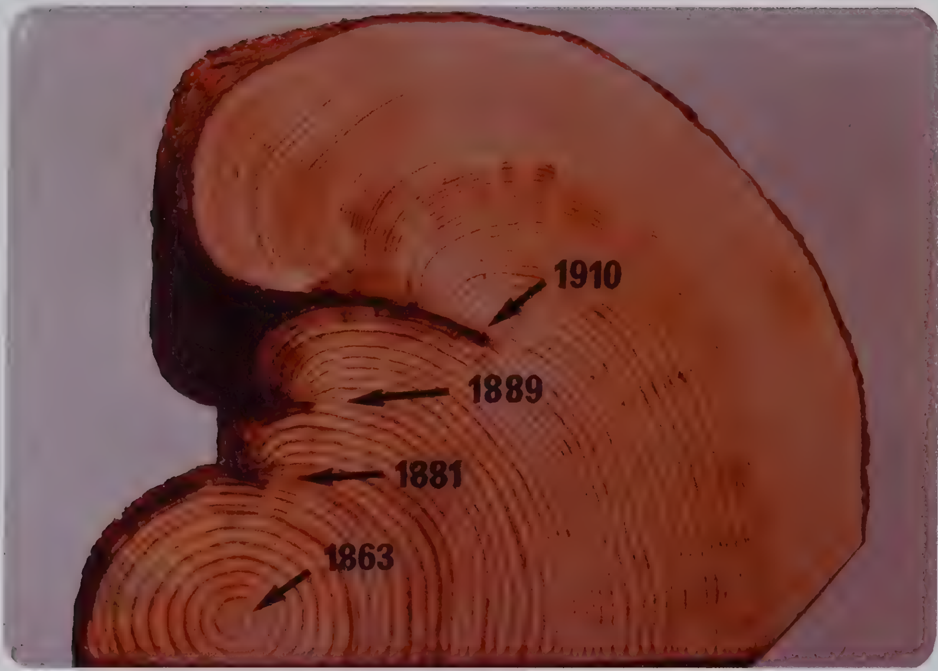
is somewhat more resistant due to its relatively thick corrugated bark. The thin and highly resinous bark of the conifers insures that even light surface fires or the less intense heat on the margins of major fires will cause scarring (Figure 4). Douglas-fir, on the other hand, is initially quite resistant to scarring due to its relatively compact, resin-free, thick, corky bark (Figure 5). However, it tends to be more frequently scarred by later fires because the wound may be covered with a thin film of resin (Lachmund 1921).

Fire scars are therefore formed on fire-susceptible tree species such as lodgepole pine by the heat of the forest fire at the margins of burns where the fire intensity is less. The initial scarring of less susceptible species such as Douglas-fir is accomplished by the actual burning away of the bark by flames and may occur within a stand where fire-susceptible species would be eliminated.

Most fire scars on fire-susceptible species are formed when fire-generated winds force hot air around the tree trunk. A vortex effect of the wind on the downwind side of the trunk intensifies the heat sufficiently to kill the cambium layer without necessarily burning away the bark. The bark initially remains closely attached to the sapwood, but in the healing process annual growth rings constituting a callus tissue form beneath the bark around the edges of the killed area. Gradually growing in from all sides, they force the old bark away from the sapwood. The bulging growth of the calluses and subsequent drying out cause the bark to crack and split, after which it gradually drops away until the sapwood is finally exposed. The period of time of exposure varies according to the rate of growth, formation of the calluses and the size of the wound. Fast-growing trees may take

Figure 4. Multiple fire-scarred section collected from lodgepole pine. Note the distinct annual rings and the thin bark characteristic of the species. Tree originated after the fire of 1863(collection date August 1975).

Figure 5. Multiple fire-scarred section collected from Douglas-fir. Charring of the face by successive fires makes determination of the fire year difficult in this species. Note the compact,thick, corky bark. Tree originated in about 1646(collection date 11 October 1975).


1910
1889
1881
1863

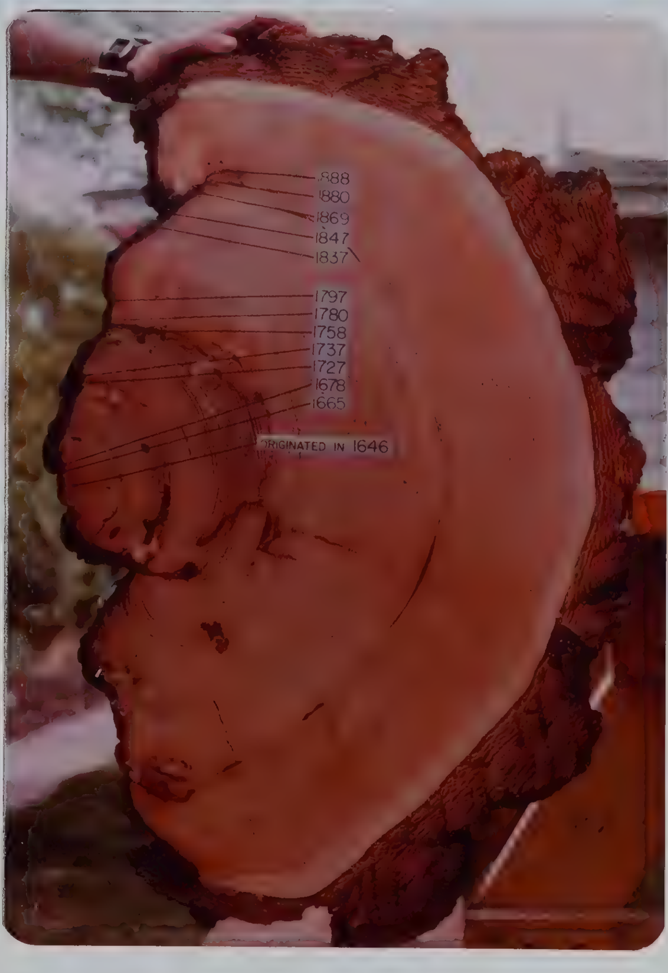

1888
1880
1869
1847
1837
1797
1780
1758
1737
1727
1678
1665
ORIGINATED IN 1646

Figure 6. Multiple fire-scarred section collected from a standing fire-killed lodgepole pine. Fire years were established by cross-dating intervals between scars with other wedges collected in the vicinity (collection date August 1975).

five to ten years before the bark falls away (Lachmund 1921) revealing the dry yellow sapwood (Figure 3).

Successive fires may form additional scars on the same tree in a similar manner. The exposed surface of previous scars may be charred or left intact. Should a second fire occur in a similar manner before the dead bark has been shed, the heat created by the vortex may be intense enough to ignite the dead bark. This may torch and kill the tree or char the dead sapwood killed and exposed by the previous fire. Several previous investigators (Clements 1910, Molnar and McMinn 1960) have used this charring as evidence for single fire scars, failing to recognize the evidence for a more recent fire. Charred fire scars proved most useful in this study for locating individuals scarred by two or more different fires.

Identification of Fire Scars. Fire scars were triangular in shape and extended from the soil surface up the trunk of the tree for some distance (Figure 3). The presence of other scars in the area with similar shapes and burn directions helped establish fire origin. A number of scars originating in the same year allowed positive identification; therefore, the evidence for the occurrence and extent of various fires grew throughout the study. As also noted by Molnar and McMinn (1960), fire-scarred trees also exhibited increased radial growth following fire.

There was little difficulty in deciding if a scar was of fire origin. Bear claw and ungulate antler injuries were distinct and easily identifiable. They were generally among snapped and broken branches high off the ground and composed of gouges and claw marks running irregularly up and down the trunk. Strips of bark were usually attached

and the wounds exuded drops of resin. Scars caused by recent mechanical injury were distingushed by their rough irregular outline with bruised and shredded bark adherring to the edge. The face of the scar was also generally abraded and branches near the scar were sometimes snapped off. Man-caused damage was not encountered because scars were collected away from roads and trails. Occasional damage from rolling boulders or wind-felled trees was distinguished by the characteristics of the scar and the presence of the damaging agent. No scars were found that could be attributed to fungal or insect damage.

Fire Scar Collection and Field Analysis. Ravines, ridges, lake shores, wetland margins and other potential natural fire boundaries were searched for scar-bearing trees. With practice, old remnant individuals and stands were recognized by their dark coarse-grained appearance on airphotos, and by the color of the bark and foliage on the ground. Old individuals of lodgepole pine possess a red-brown flaky bark with a dark dull-green canopy that invariably was damaged by dwarf mistletoe or wind. Such stands were characterized by large amounts of deadfall made up of old toppled individuals. Fire-scarred trees were sometimes easily recognized from a distance by carpenter ant activity and subsequent pileated woodpecker damage at the base of the trunk.

Once a stand was located, the fire-scarred individuals were examined to find the tree that harbored the largest number of scars. The individual was then inspected to find the portion of the scar that would yield the most information with the least amount of effort. Care was taken to choose the portion of the scar that would give the greatest

distance between multiple scars to facilitate easy interpretation of the rings.

A section was removed with a 75 cm bow saw. The most efficient way to remove the scar was to first cut past the centre of the tree perpendicular to the scar at the desired height, and then, carefully aligning the saw with the endpoints of the first cut, angle the second cut from above to meet the first. Accuracy improved with the size of the section removed.

I found it most desirable to age the fire scar section in the field immediately after collection in order to build a knowledge of the fire chronology as rapidly as possible. This also enabled me to map and gain a mental image of the extent of individual fires and allow a follow-up of confusing ages or dates (Heinselman 1973, 1975). When the desired section was obtained, the clearest portion of the smoothest surface was shaved smooth with a sharp knife and a guide line drawn from the scar to the outer surface with a fine felt-tipped pen. A 10X hand-lens was used to make the count. If the rings were indistinct the application of saliva would generally make the count easier. Counts were made from the inside out and rechecked by a count from the outside in. This procedure was followed for each scar on multiple scarred sections. Sections were removed from a site until I was confident that the data represented all of the fire dates of a stand. All sections were labelled, recorded and saved for future verification.

The annual ring whose growth was interrupted by fire is called the "fire annulus". The choice of the fire annulus may vary between investigators and therefore could constitute a source of error in fire history investigations (M.L. Heinselman and G. Fahnestock pers. comm.

June 1975). To determine the fire annulus on the clearest portion of the scar, a three step procedure was established (Figure 7):

1) Five or more rings were counted toward the pith from the scar at the callus close to the face.
2) The ring was traced to the pen mark on the shaved portion of the section.
3) The five or more rings were counted back toward the outside along the pen mark and the fire annulus established.

The proper year from which to subtract the ring count to determine the actual fire year may also be a source of error among investigators. All ring counts were subtracted from the year previous to the year in which the collection was made, since the current year's summerwood had not been formed during the collecting period. Fire scar sections collected at known burns in the study area verified this technique.

One large Douglas-fir tree was felled and a complete cross section cut from the base of the trunk with a two-man crosscut saw (Figure 5). A large wedge was removed from a second individual. These sections were not aged in the field but returned to the lab and treated as outlined below. The fire data from these two sections illustrated Douglas-fir's value in extending the fire chronology. However, it is suggested that it is not necessary to fell a Douglas-fir to obtain its full complement of fire dates because the full section did not reveal hidden fire scars for the already known period of record. Rather, if a two-man crosscut or chain saw is available and can be carried in the field, a carefully selected section from the fire-scarred area of the tree will suffice for fire history investigations.

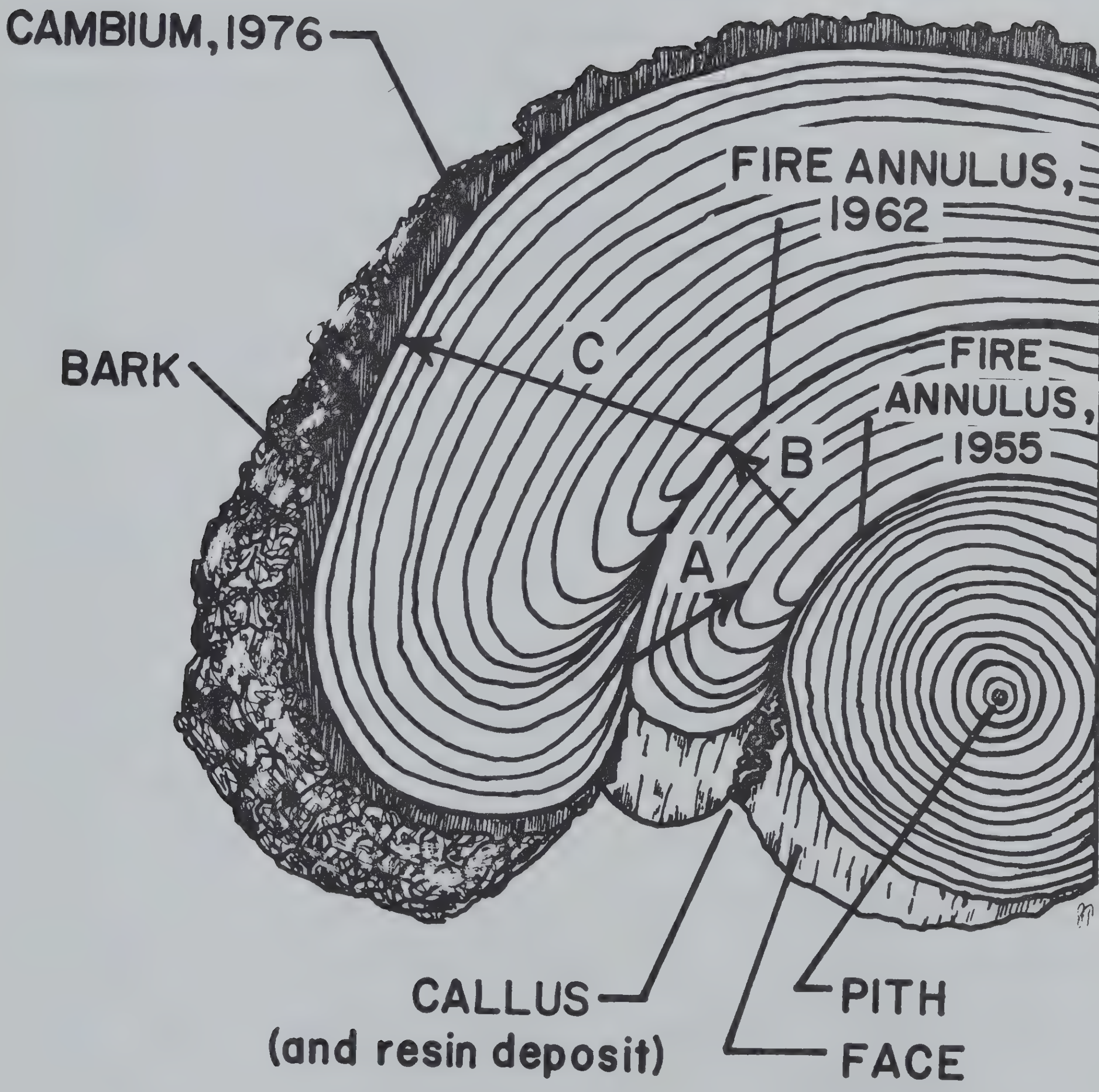


Figure 7. Diagramatic sketch of a typical lodgepole pine fire scar. The three step aging procedure is as follows: Five or more rings are counted toward the pith(A), and recounted toward the cambium to establish the fire annulus(B). Summerwood rings are then counted towards the cambium(C). The fire year is then established by subtracting the count from the previous year in which the collection is made.

<u>Laboratory Preparation and Aging of Fire Scar Data</u>. The surface produced by cutting a fire scar section with a bow or crosscut saw is too rough to show adequate detail of the ring structure. Shaving a portion of the section in the field reveals the annual rings in sufficient detail to provide a field estimate of fire dates. In some instances, however, the growth rings were so close together that they could not be aged in the field in such a manner. Further surfacing was therefore necessary before dating could be accomplished.

Visibility and detection of microscopic layers is dependent on careful preparation (Glock 1937). Specimens were air dried and unnecessary wood and bark pruned from the edges. Fragile and broken sections were mended with a waterproof white glue and secured with masking tape. Once they had dried, they were sanded on the flattest surface with successively finer grits. The surface was first flattened with coarse grit (#80) flint sandpaper on a table sander. The flattened surface was polished by hand using a medium grit (#150) followed by a fine grit (#220) flint sandpaper mounted on a sanding block. Care was taken to entirely remove the sanding marks left by the preceding grit. The polished surface of the fire scar was then rubbed with a pad of very fine (#000) steel wool to remove rough edges and dust from the cells.

Once the exposed surface was polished, it was examined with a zoom stereomicroscope at low (6-12X) magnification. Fire scars exhibiting suppression zones were stained with safranin (Henry and Swan 1974). Ages and dates of most collected specimens were then determined accurately and rapidly using the technique outlined in the preceding section. In some instances the growth rings were so close

that a section had to be taken with a razor blade and the count made with a compound microscope.

Laboratory Preparation and Aging of Stand Origin Data. After each day of collection, increment cores were removed from the storage containers and glued with waterproof white glue and taped down to dry into specially prepared wood mounting trays. The 1x1x40 cm trays were grooved on one side so that approximately one half of the core was left protruding above the surface. Since annual rings are more conspicuous when seen in cross section or transverse view than in a radial or side view, care was taken to orient the core so that a transverse section could be made on the exposed surface. Orientation was most easily accomplished by observing the pith. When present, the pith appeared as a small dark spot in a transverse view and as a vertical band in radial view. If the pith was missing, orientation was determined by a curvature of the inner rings (Stokes and Smiley 1968).

After the glue had set and the core dried, the tape was removed and the core was surfaced for study. Sanding of the core was done in the same manner as for the fire scar sections except that the exposed surface was flattened with a medium grit (#150) and polished with a fine (#220) and very fine grit (#320) flint sandpaper. A stereomicroscope was used to age the polished cores.

Dates of origin of the trees were calculated in two steps (Henry and Swan 1974). First, the rings of the increment core were counted and recounted. If a count differed, it was taken until agreement was reached. Secondly, 15 lodgepole pine were collected from throughout the study area and sections removed at ground level and 25 cm

to determine the number of years the cores taken at the standard boring height of 25 cm were short of stem age. For lodgepole pine, the average difference was four years (3.73) with a standard deviation of two years (2.31). This value was added to all cores to establish dates of origin.

Construction of the Fire Chronology

Verified fire-scars were used to construct an initial fire chronology. Scar dates were tallied to indicate peak years of occurrence which were arbitrarily defined to be fire years documented by at least two fire scars. These peak years were plotted on airphotos to discern patterns of occurrence.

Scar dates of this initial fire chronology that were clustered around a peak fire year and exhibited an overlapping pattern when plotted on the airphotos were verified and replotted to determine whether they represented separate fires, or an error in aging. A final fire chronology was constructed from this analysis.

Construction of the Stand Origin Map

A stand origin map (Heinselman 1973) depicts different forest stands of the study area and the fire or fires from which elements of the stands originated. Airphoto interpretation, extensive field notes and stand origin dates verified with fire-scar dates were used to construct the stand origin map.

Black and white airphotos for 1949 (A12406, A12407), 1966 (A19662, A19670), 1972 (A23015), 1973 (A23238) and infra-red imagery for 1975 (A37213IR) were used to reinterpret the vegetation mosaic of the

study area with a Carl Zeiss Interpretoskop. The higher quality of more recent photos insured a detailed coverage of the area even though most fire margins were more readily identified on older photos. A zoom transfer scope was used to transfer stand boundaries interpreted from these various airphotos to the enlargements that were carried in the field.

Acetate overlays of the stand origin dates and the fire-scar dates were prepared over the airphoto blowups. The study area was then systematically analyzed stand by stand to determine the actual date or dates of origin for all stands. Field notes on fire sign, stand structure and burn direction facilitated interpretation of the stand origin dates and fire-scar record. Where no data were obtained, the stand origin dates were extrapolated from the nearest similar stands with known origins (Heinselman 1973). The final stand origin map of the study area was prepared by transferring the stand boundaries from the airphoto enlargements to 1:50,000 topography maps with the transfer scope.

Construction of the Fire Year Maps

A series of fire year maps for the study area was prepared from the stand origin map and field evidence, using techniques first outlined by Heinselman (1973).

Stands showing evidence for a specific fire year were transferred to acetates from the stand origin map to gain a perspective of the location and potential areal extent of a fire. Using the above acetates, actual fire maps were prepared by connecting the mapped limits of stands that resulted from coalescent burns of the same year

(Heinselman 1973).

Heinselman states that "a problem in preparing such maps is to reconstruct the paths of burns that have since been overlapped by later fires. Stand boundaries alone suffice to map the *last* fire in an area, but extrapolation is necessary to trace earlier fires." To help circumvent this problem in this study, field evidence such as burn direction, slope, aspect and a knowledge of fire behavior were employed to extrapolate the areal extent of each fire. Natural fire breaks, prevailing weather patterns and topographic moisture regimes were used to arrive at the final fire boundaries.

RESULTS

Fire Chronology, 1665-1975

A fire history chronology of the Athabasca River valley around Jasper townsite has been established for the 310 yr period, 1665-1975. The dates of 72 fires known to have occurred in the study area are listed in Table 2. A total of 664 fire-scars from 435 trees was used to establish the chronology.

All scar dates are from lodgepole pine or Douglas-fir. No variations in dates were encountered for lodgepole pine that were due to false or missing rings. Douglas-fir, however, was found to vary by ±2 years because of insect damage, resin deposits, and charring of the fire scar by subsequent fires. Scar dates back to 1758 and stand origin dates to 1714 were obtained from lodgepole pine. Douglas-fir was used to project the chronology back to 1665. The oldest-aged lodgepole pine was 264 yrs and the oldest Douglas-fir was 570 yrs.

Some generalizations can be made from Table 2. The interval between fires is smaller from 1895 to 1908 than either before or after this period. Fires occurred at 1-9 yr intervals from 1837-1971, and were much wider from 1665 to 1834, varying from 1-36. The fire scar evidence shows that there was a fire every year between 1894 and 1908.

For this study, a "major fire year" was defined as a year in which the fire or fires covered 1.2% or more of the study area, or about 500 ha. Such fires occurred at longer intervals varying from 1 to 27 yrs, and account for most of the total area burned from 1665 to 1975. There was a notable decline in the portion of the study area burned

Table 2. Fire scar dates[a], intervals between fires, and areal extent of individual fires for the Athabasca, Miette and Maligne River valleys around Jasper townsite, Jasper National Park, Alberta.

DATE OF FIRE	INTERVAL SINCE LAST FIRE (YEARS)	MAJOR FIRES[b]	INTERVAL SINCE LAST MAJOR FIRE (YEARS)	PORTION OF STUDY AREA BURNED (%)	KNOWN AREA OF BURN (km^2)	NUMBER OF FIRE SCARS FOUND
1971	6			0.03	0.22	1
1965	1					1
1964	5					1
1959	3					1
1956	2					1
1954	2					1
1952	1					1
1951	1					2
1950	4					1
1946	2			0.02	0.09	1
1944	1					1
1943	4					1
1941	1					4
1940	1					1
1939	3					1
1936	2			0.2	0.68	5
1934	1					1
1933	1					2
1932	3					1
1929	1					1
1928	3					2
1925	2					1
1923	5					1
1918	3					1
1915	1					9
1914	4					2
1910	2					8
1908	1	**		1.4	5.98	17
1907	1			0.8	3.52	7
1906	1	**	2	8.1	34.19	34
1905	1	**	1	4.8	20.47	36
1904	1	**	1	1.2	5.29	4
1903	1					2
1902	1			0.4	1.71	3
1901	1			0.3	1.17	4
1900	1			0.2	0.85	2
1899	1					1
1898	1			0.1	0.21	4
1897	1			0.1	0.21	2
1896	1			0.3	1.07	3
1895	1			0.1	0.32	3
1894	2			0.1	0.16	1
1892	3					1
1889	1	**	15	78.5	338.39	287
1888	5	**	1	2.7	11.64	16
1884	1	**	4	1.8	7.90	7
1883	3	**	1	2.0	8.64	13
1880	2	**	3	1.2	5.29	5
1878	2					2
1876	7					1
1869	6	**	11	1.9	8.00	7
1863	2	**	6	5.5	23.59	12
1861	3	**	2	1.8	7.79	2
1858	7	**	3	8.7	37.68	13
1851	4			0.1	0.32	3
1847	1	**	11	52.3	225.45	34
1846	9	**	1	5.3	22.74	18
1837	3	**	9	18.5	79.74	14
1834	13	**	3	5.6	24.23	13
1821	10			0.2	0.64	2
1811	1					1
1810	3					1
1807	10	**	27	8.2	35.44	3
1797	17	**	10	6.7	28.71	10
1780[c]	9	**	17	2.4	10.14	2
1771	13			0.4	1.49	1
1758	21	**	22	50.9	219.42	6
1737[c]	10	**	21	15.5	67.04	2
1727[c]	13	**	10	12.8	55.08	2
1714[c]	36	**	13	2.8	11.96	1
1678[c]	13	?		0.8	2.92	1
1665[c]		?		0.9	4.05	1
						Total=664

[a]All scar dates are from lodgepole pine unless otherwise noted.

[b]A major fire constitutes a fire burning more than 500 hectares(1.2% of the total area).

[c]Tentative dates based on two Douglas-fir fire sections taken in October 1975. Fire dates of Douglas-fir have been found to vary by ±2 yrs when compared to known dates of the area they were collected in.

after 1908.

Many fires appear to have occurred not singly, but as clusters (*e.g.* 1904-1906, 1880-1889, 1858-1869, 1834-1847, 1780-1807, 1714-1758), and are separated by 11-27 yr intervals with a mean of 17 yrs. Furthermore, the total areal extents of successive major fires within clusters generally increased exponentially with time, terminating with very large fires such as those in 1758, 1847 and 1889 (Figure 8). Between peaks, fire size dropped to a number of small fires before beginning again. The more erratic smaller cycles preceded the biggest fires. For example, the oscillations in fire size before the 1847 fires are not as erratic as those that occurred prior to the 1889 fire year. This cyclic pattern of fluctuations in the size of past fires is abruptly lost after 1910.

Fire Scar Sample Size and Age Class Distributions

The number of fire scars per time interval, follows the same cyclic trends as Figure 8, and is proportional to the area covered by historical fires in the study area (Figure 9). Oscillations in frequency for more recent fires are more evident in Figure 9 than Figure 8. Fires increased in frequency but decreased in size after 1913. As well, the evidence for past fires inevitably declines with time.

The diversity of age classes on the landscape left by past fires is evident in Figure 10. Sample size showed the same cyclic trends as in Figures 8 and 9 and is proportional to the total area burned. Lodgepole pine established on recently burned areas 1-20 yrs after a fire, averaging 4 yrs but varying from site to site. There is a gradual increase in age classes with time, periodically interrupted by jumps in

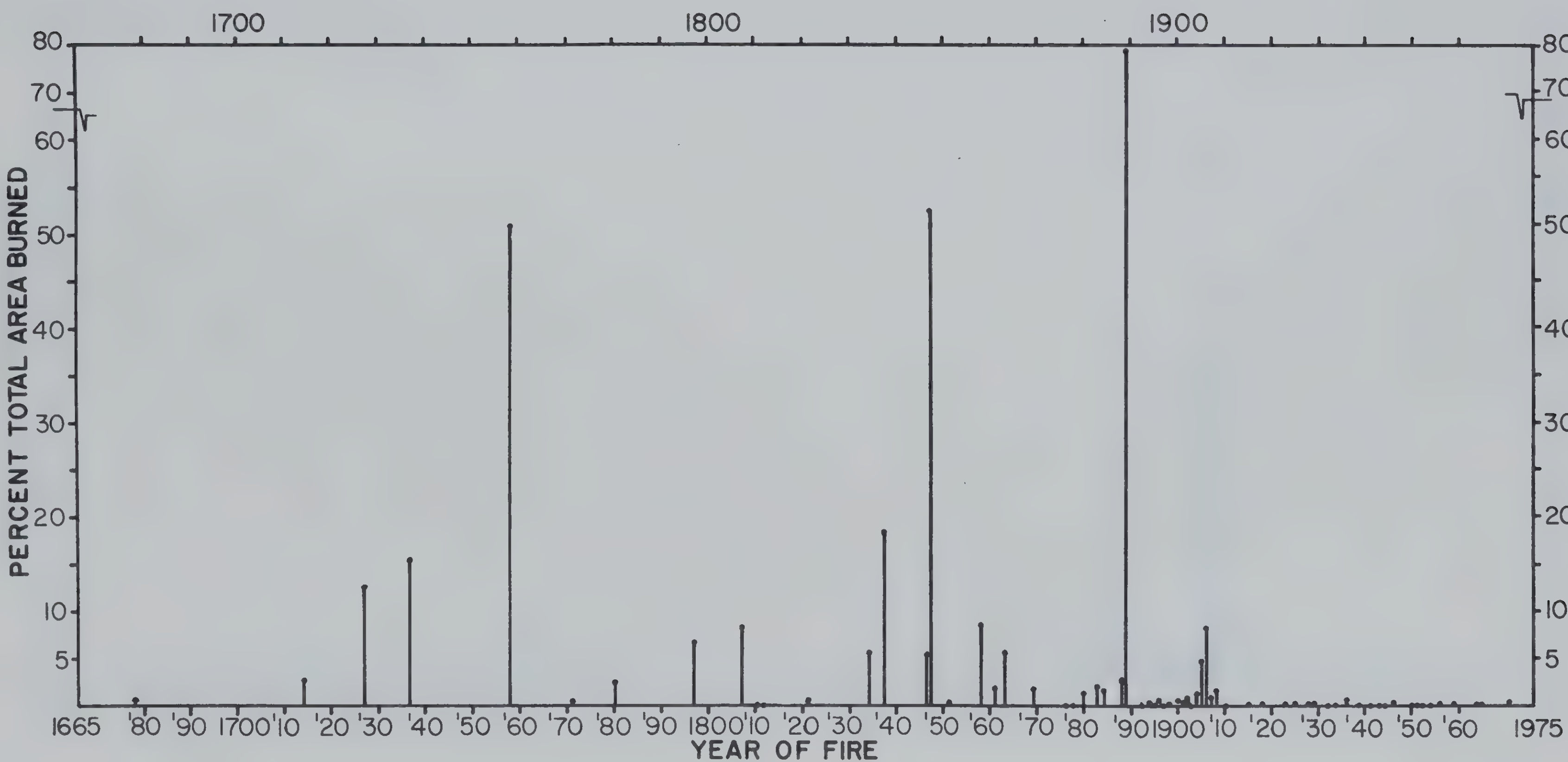


Figure 8. Percent of the total area burned per year for all fires, 1665-1975, in the Jasper townsite study area.

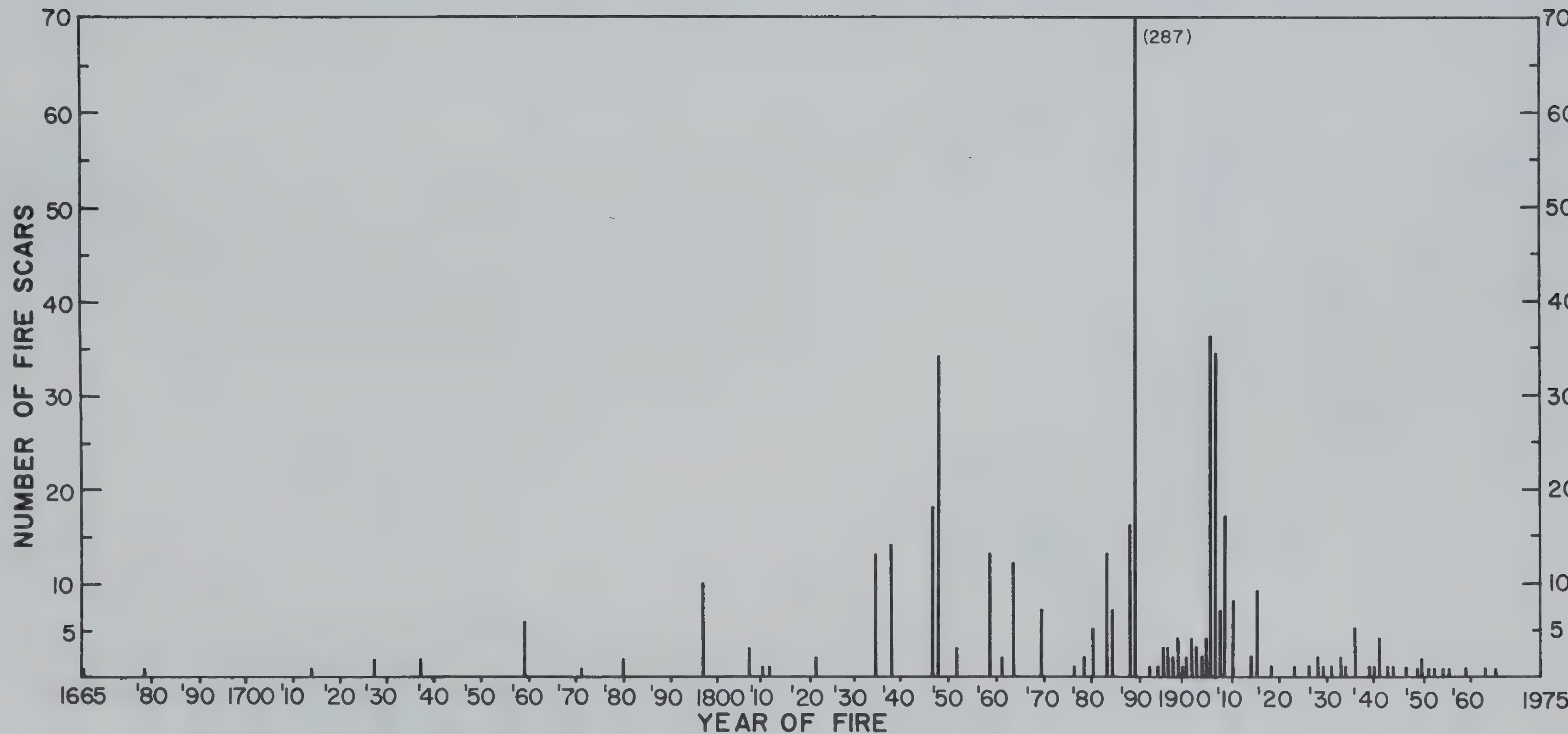


Figure 9. Number of sample trees scarred during each fire year in the Jasper townsite study area.

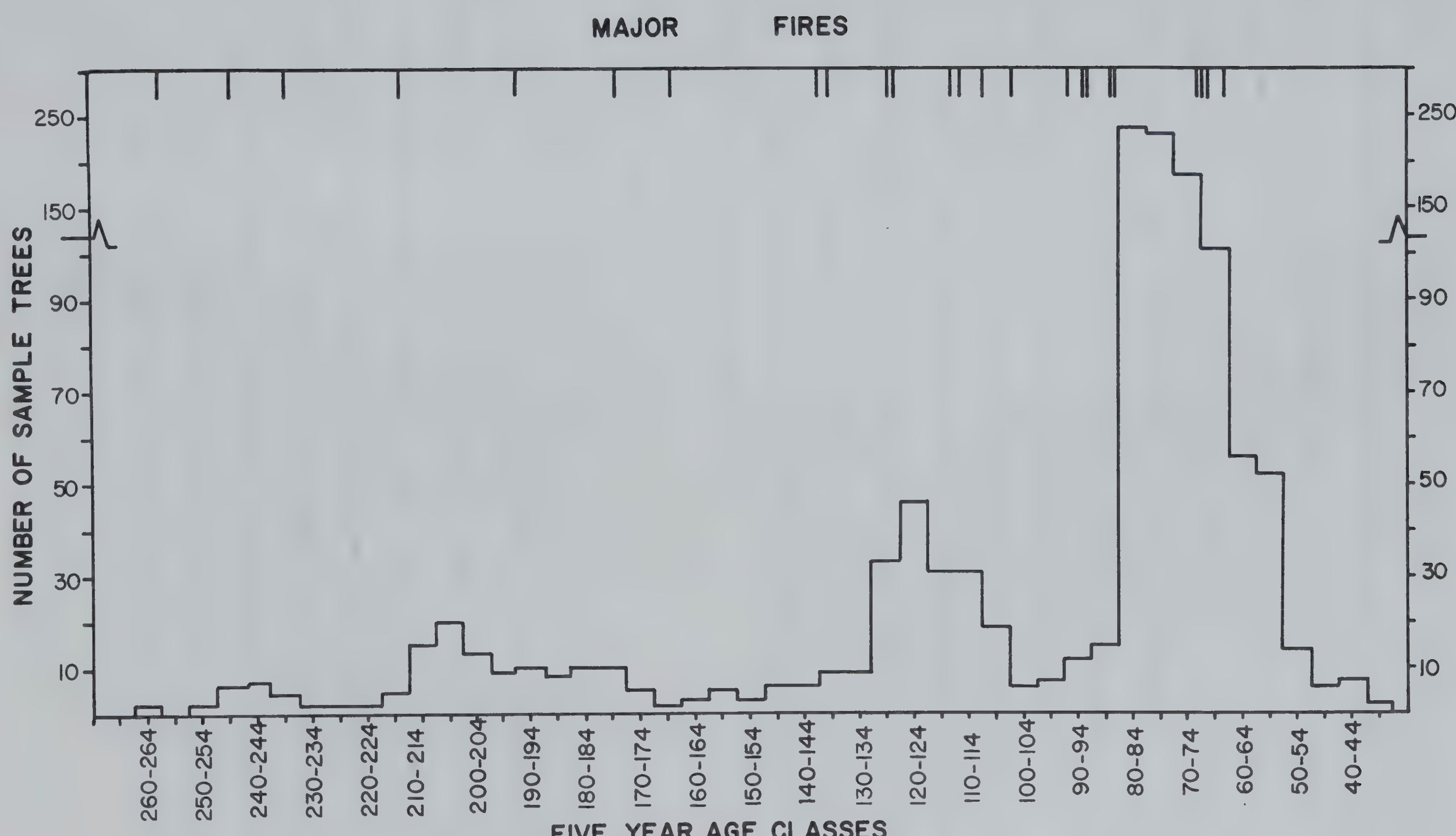


Figure 10. Frequency distribution of stand origin dates by five-year age classes from 3,388 lodgepole pine in the Jasper townsite study area. The tic marks along the top of the histogram denote major fire years as determined from fire-scar dates.

age classes for major fire years. Most of the forested landscape today originated after the major fire years 1889, 1847 and 1758. The greatest portion of the lodgepole pine forests in the study area originated after the 1889 fire. Peaks traceable to other major fire years are evident but less pronounced. There are no additional age classes on the landscape since 1919, or about 55 yrs ago.

The decline in stand origin and fire scar sample sizes over time (Figure 11) is attributable to elimination of evidence by subsequent fires and the limited longevity of tree species in the study area. Loss of actual fire-scar dates is further accounted for by the limited durability of fire-killed snags, discouraging cross-dating intervals. In contrast, the decline in evidence for more recent fires, despite a large sample size, is attributed to the implementation of effective fire suppression after 1913.

Stand Origin Map

The fire history of the study area is depicted on the stand origin map (Figure 12, *see* attached packet). Stand origin dates were determined from ages of 3,388 lodgepole pine. These were verified with fire scar dates whenever possible. Each area on the map originated after the indicated fire year. Sometimes stands within an area exhibited such complex age structure that elements dating from different fires could not be separated in airphotos or on the ground. Such complex areas are numbered on the map and their stand origin dates are found in the legend. Areas less than 6 ha in size are not shown and are included with larger adjacent stands.

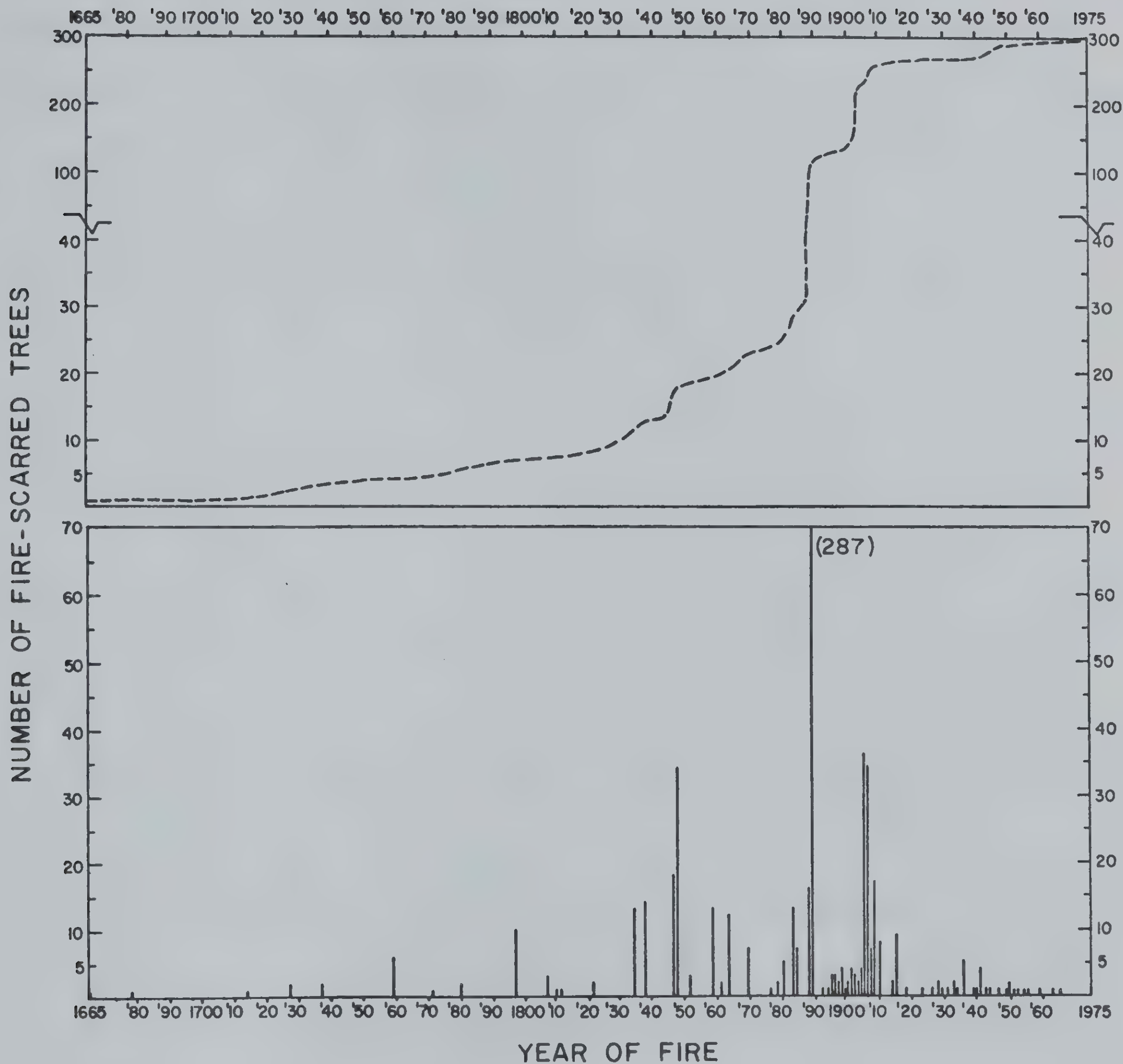


Figure 11. Number of sample trees scarred during each fire year showing the decline in fire-scar sample size over time. The dashed line indicates the total number of fire-susceptible trees in the sample. Fire-susceptible trees are those already scarred at least once (method after Arno 1976).

As indicated in the Methods, some areas such as the upper slopes between Muhigan (52°50'N 118°13'W) and Whistlers Mountains, and the Colin Range, were so steep and rugged that it was impossible for me to reach them. In these areas stand origins are extrapolations of airphoto interpretations from lower elevations. For example, airphoto interpretations showed a recent fire (before 1949) near timberline at the inaccessible head of Muhigan Creek on the north-facing slope above the Miette River. The area is delineated on the stand origin map, but date of origin remains unknown.

The stand origin map portrays a complex landscape mosaic of age structures as the result of past fires. Extensive tracts of even-aged forests at middle to high elevations originated after the largest major fires such as 1847 and 1889. In terms of both age structure and the associated fire history, valley bottom areas are more complex than those at higher elevations. This indicates that fires were more frequent and less intense at lower elevations, leaving many remnants from earlier fires. Within the valley bottoms, the fire history is most complex in the area bounded by Pyramid Lake, Maligne Canyon and Jasper townsite.

Areas containing no observed evidence for past fires are found at high elevations and are especially prevalent on the slopes of Pyramid and Signal Mountains (Figure 13). More of this "unburned" area is found on north- and east-facing slopes than on south- and west-facing slopes.

Fire Year Maps

No major fires have occurred in the study area since 1908. A

Figure 13. Portions of the Jasper townsite study area in which no evidence for past fires was observed.

small lightning fire burned 22 ha of the subalpine forests on Whistlers Mountain in 1971. In 1946, a small fire on the north shore of Minnow Lake consumed 9 ha. The fire scar and stand origin information revealed a 1936 burn on the north shore of Caledonia Lake that covered 68 ha. These three fires have been verified by historical records. Unfortunately, all other park records concerning the location and size of past forest fires before 1968 have been destroyed (S.F. Kun, Director, Natl. Parks Branch, Parks Canada pers. comm. 10 Dec. 1976). As a consequence, fire periodicity and the pattern of past fires must be based on the fire-scar record and stand origin data.

Maps have been prepared for 45 fire years prior to 1910 (Figures 14-48). Fires after 1910 with scar evidence are found on the stand origin map (Figure 12). The extent of earlier fires is based on 611 fire scars and the stand origin map. These maps provide my best estimates of the location and areal extent of the fires for each fire year. I am confident that the fire maps are accurate back to at least 1821. Before this date, extents of burns indicated by the maps are conservative estimates, and may actually have been substantially larger. Separate areas with fire scar and stand origin data for a given fire year may have been part of the same fire, but no evidence was found to suggest that this was the case (Figures 36, 39, 44).

The area shaded on the fire year map does not necessarily mean that the fire consumed the entire area indicated. The widespread occurrence of old remnant individuals bearing numerous fire scars is testimony that fire passed through the area but did not kill the entire stand (Figure 12). The estimated area covered by each fire year and the

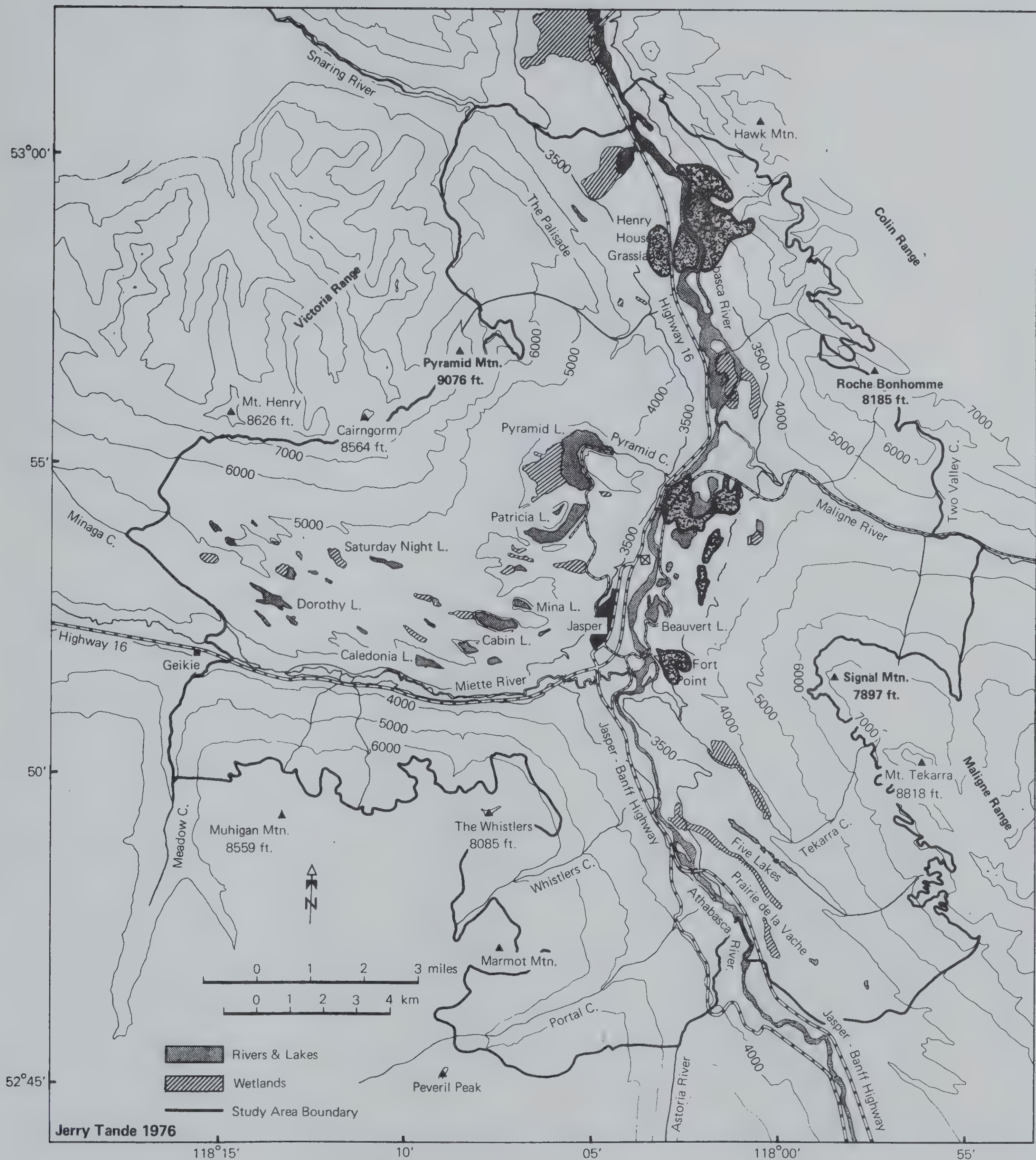


Figure 14. Areal extent of the fires of 1908 around Jasper townsite, J.N.P.

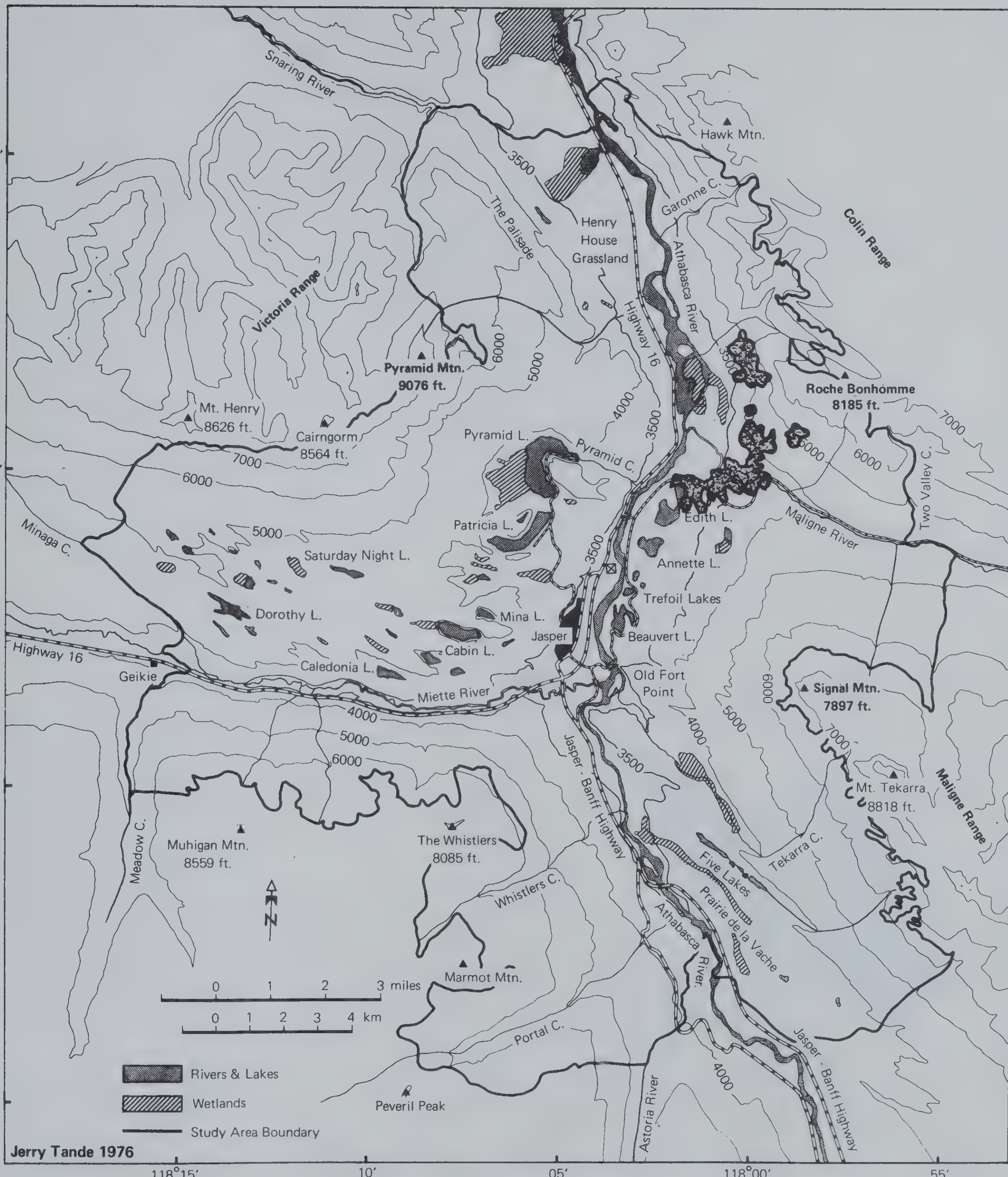


Figure 15. Areal extent of the fires of 1907 around Jasper townsite, J.N.P.

Figure 16. Areal extent of the fires of 1906 around Jasper townsite, J.N.P.

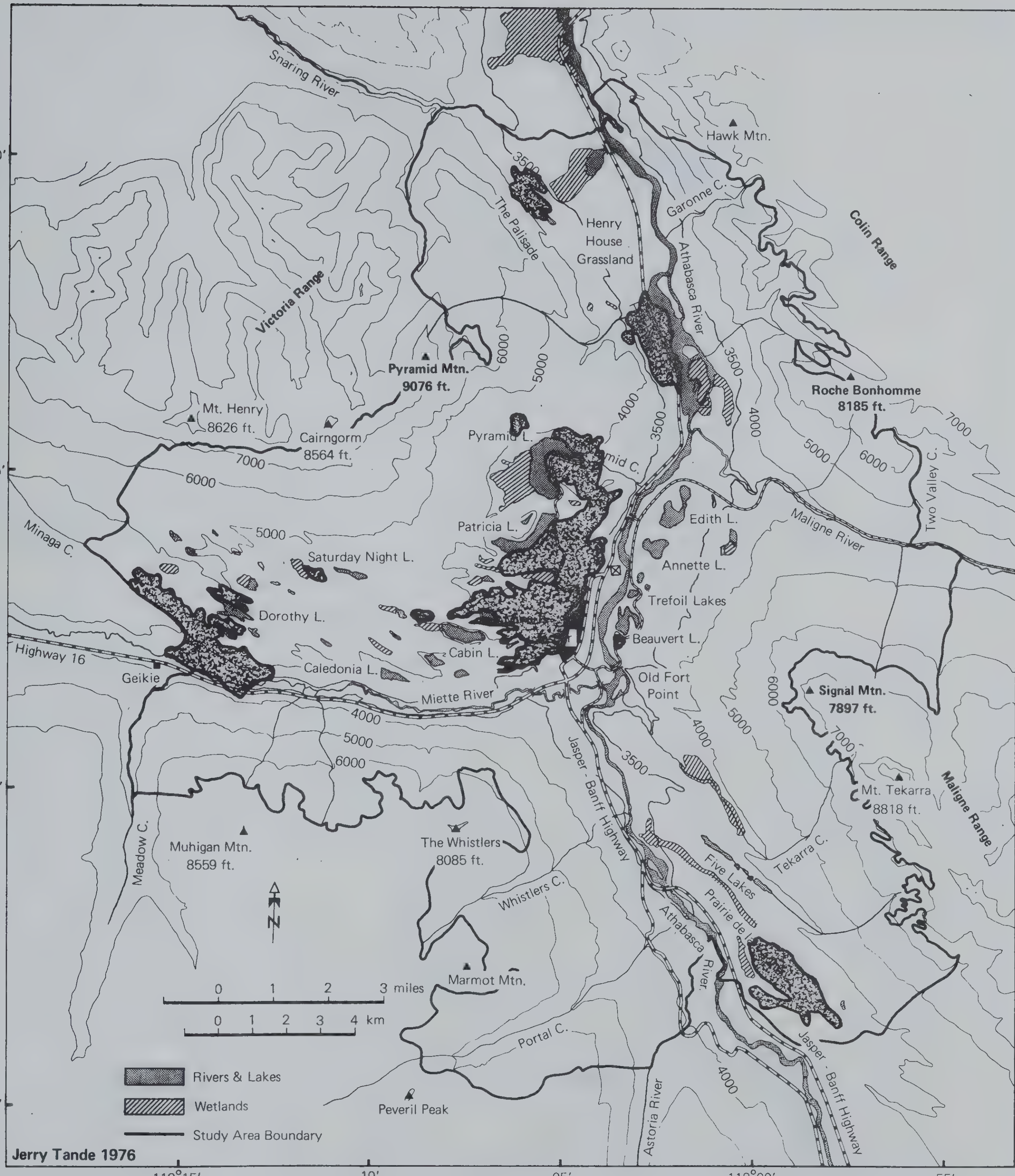


Figure 17. Areal extent of the fires of 1905 around Jasper townsite, J.N.P.

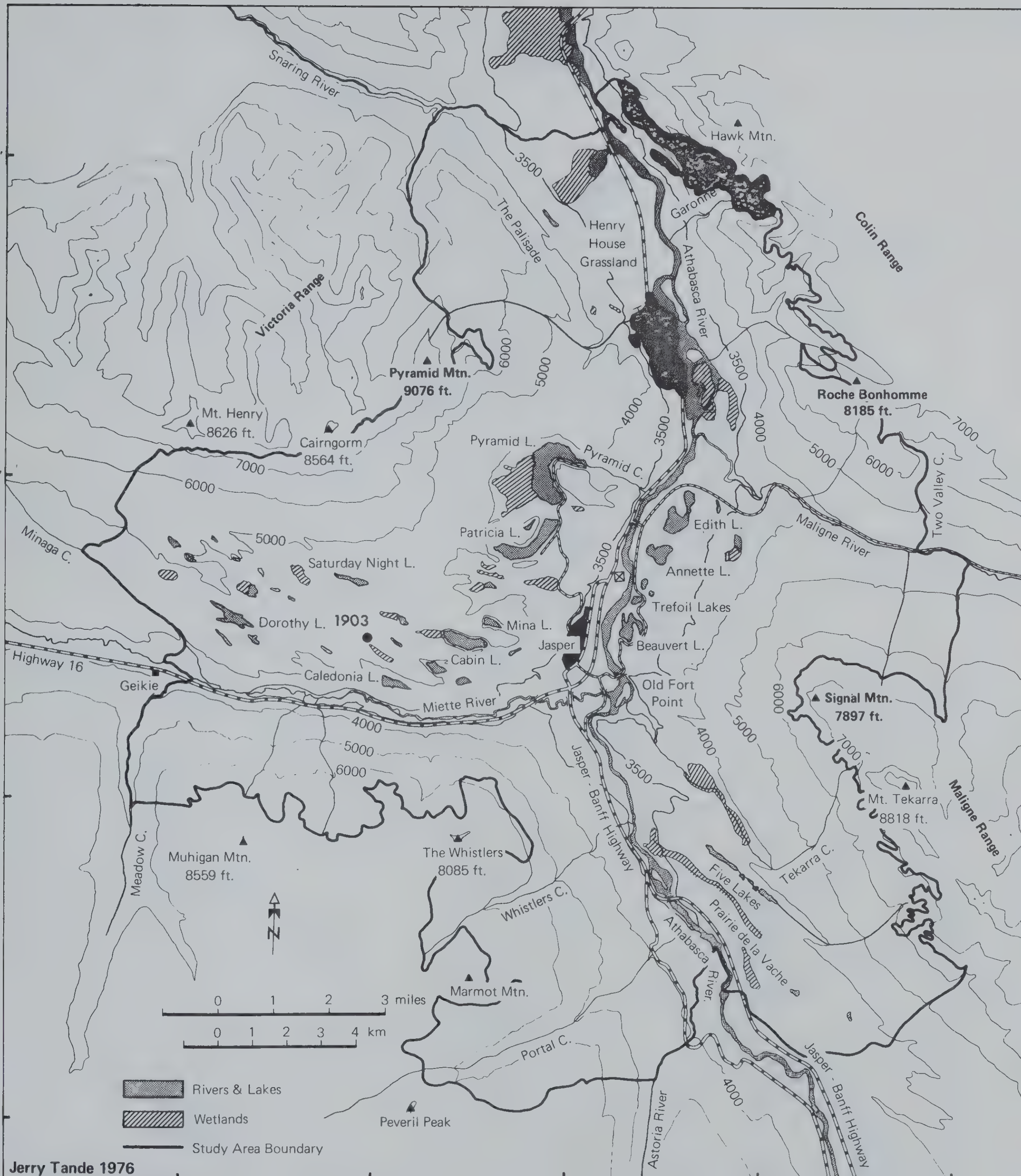


Figure 18. Areal extent of the fires of 1903-1904 around Jasper townsite, J.N.P.

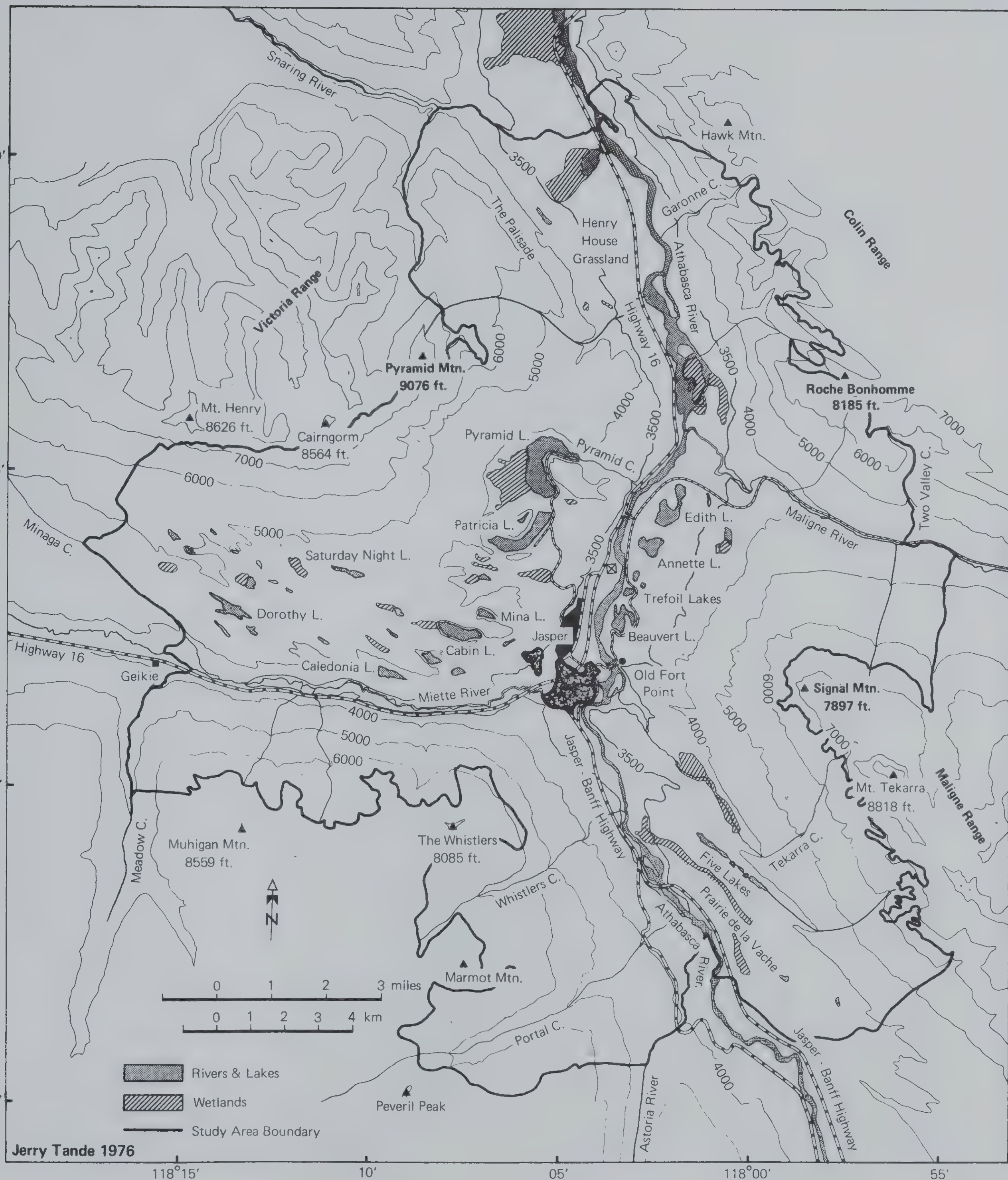


Figure 19. Areal extent of the fires of 1902 around Jasper townsite, J.N.P.

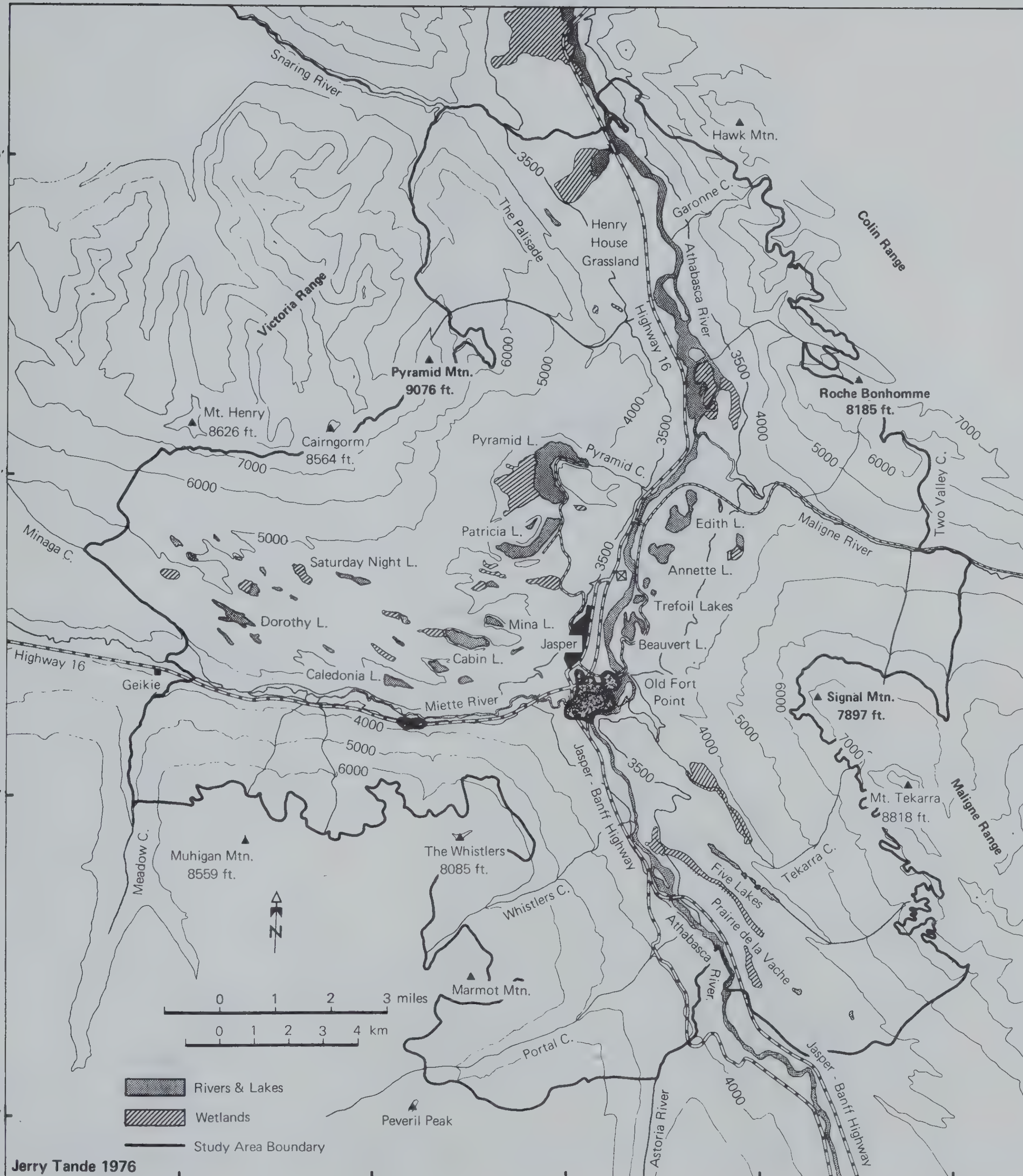


Figure 20. Areal extent of the fires of 1901 around Jasper townsite, J.N.P.

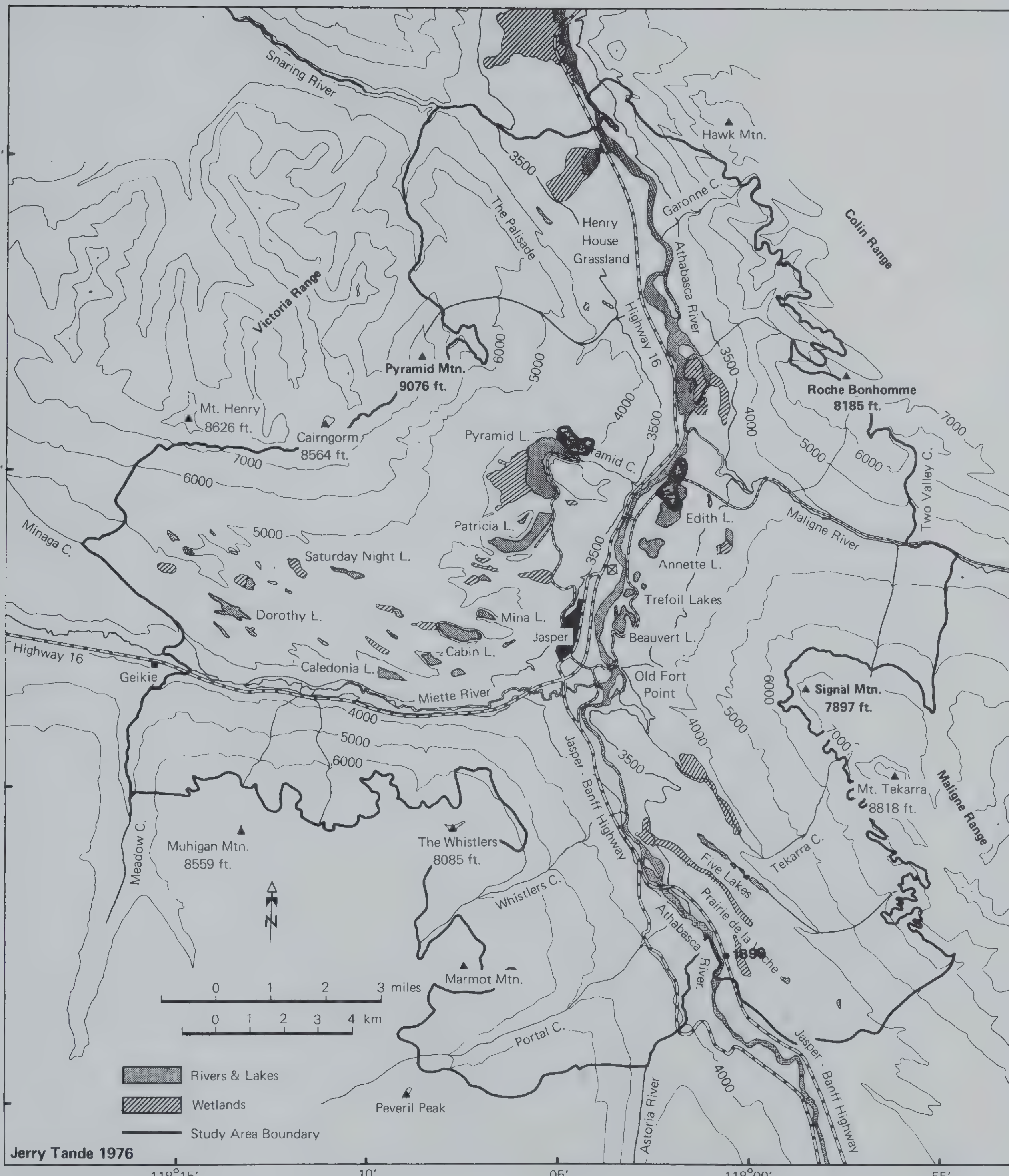


Figure 21. Areal extent of the fires of 1899-1900 around Jasper townsite, J.N.P.

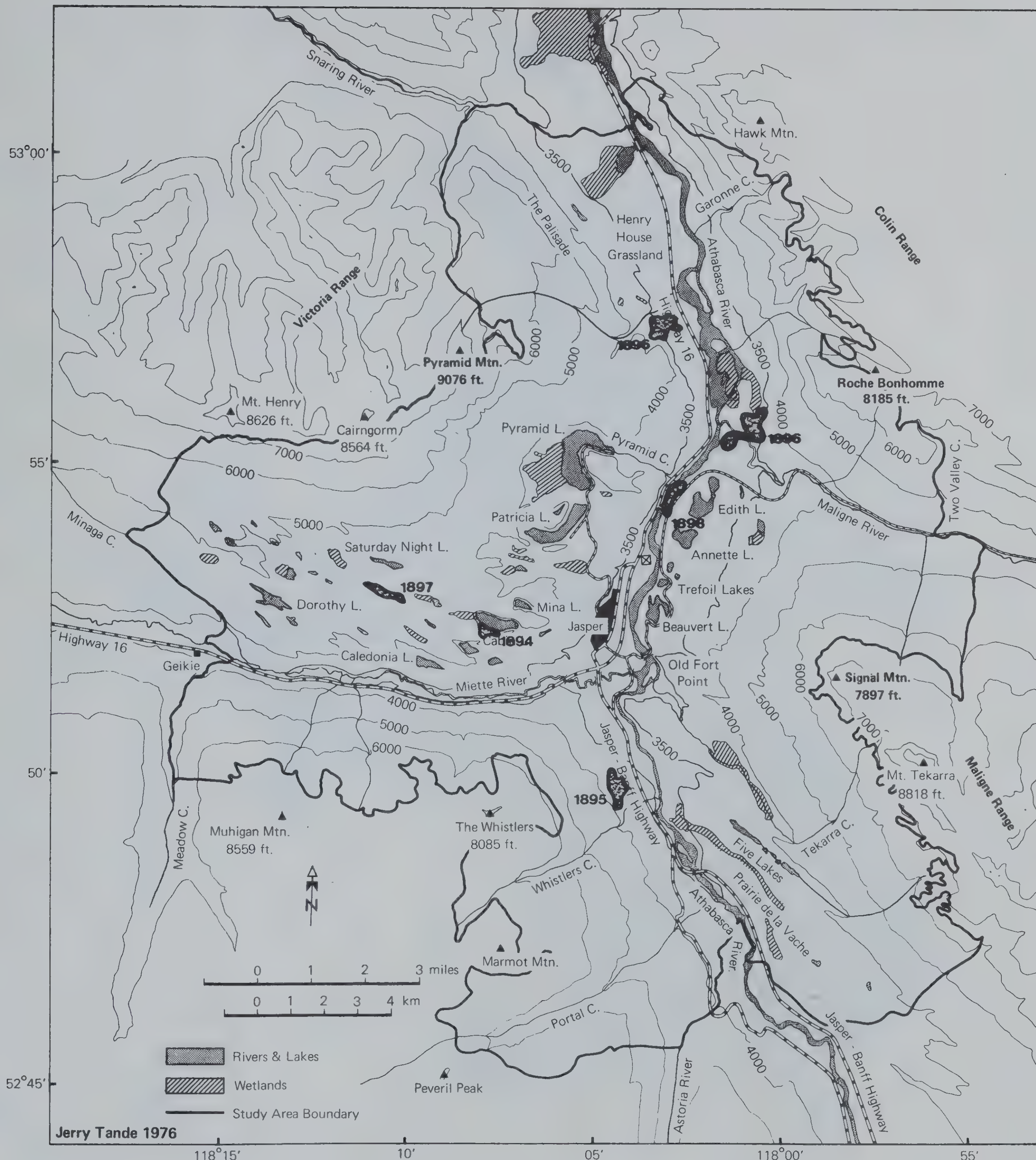


Figure 22. Areal extent of the fires of 1894-1898 around Jasper townsite, J.N.P.

Figure 23. Areal extent of the fires of 1889 around Jasper townsite, J.N.P.

Figure 24. Areal extent of the fires of 1888 around Jasper townsite, J.N.P.

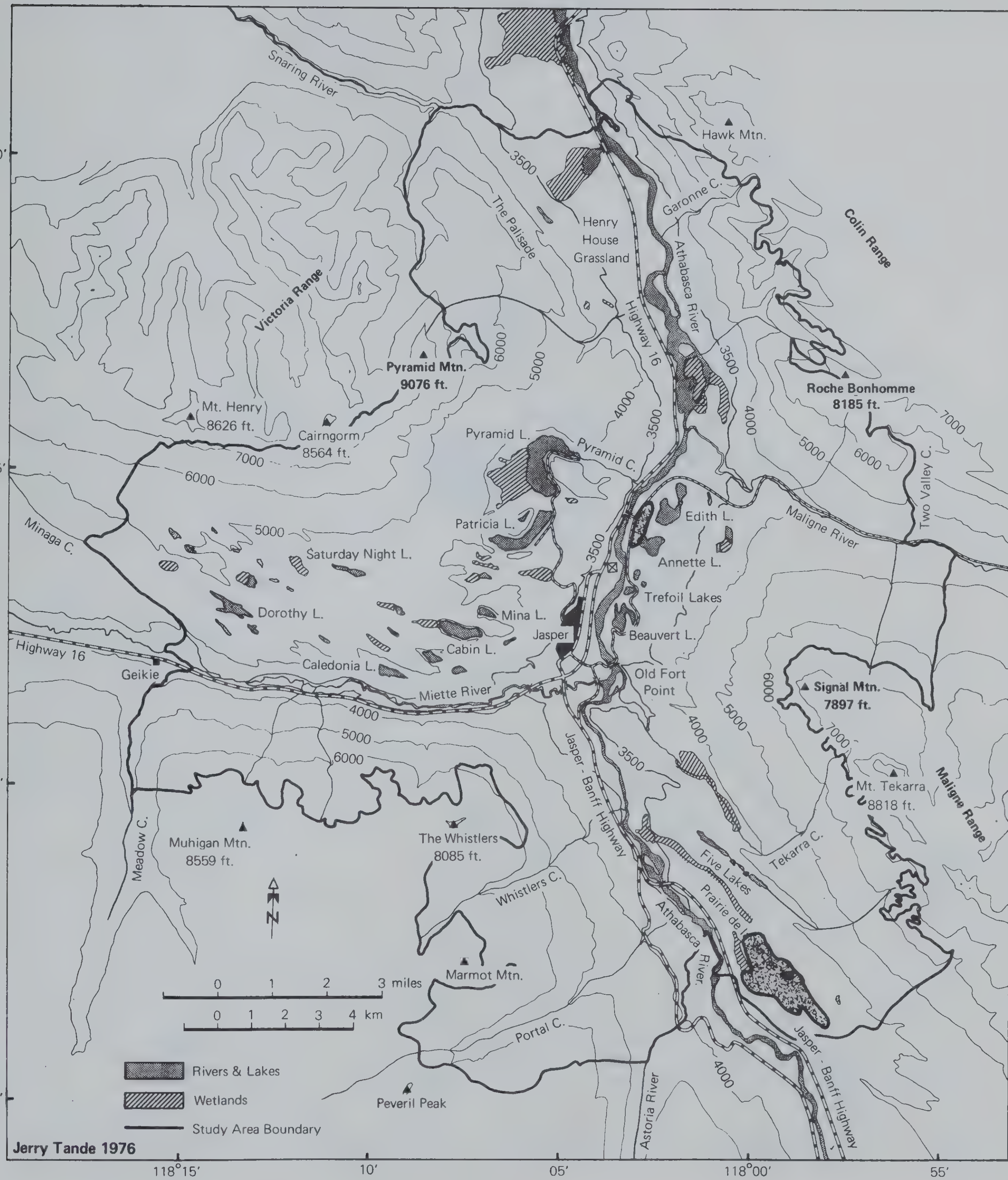


Figure 25. Areal extent of the fires of 1884 around Jasper townsite, J.N.P.

Figure 26. Areal extent of the fires of 1883 around Jasper townsite, J.N.P.

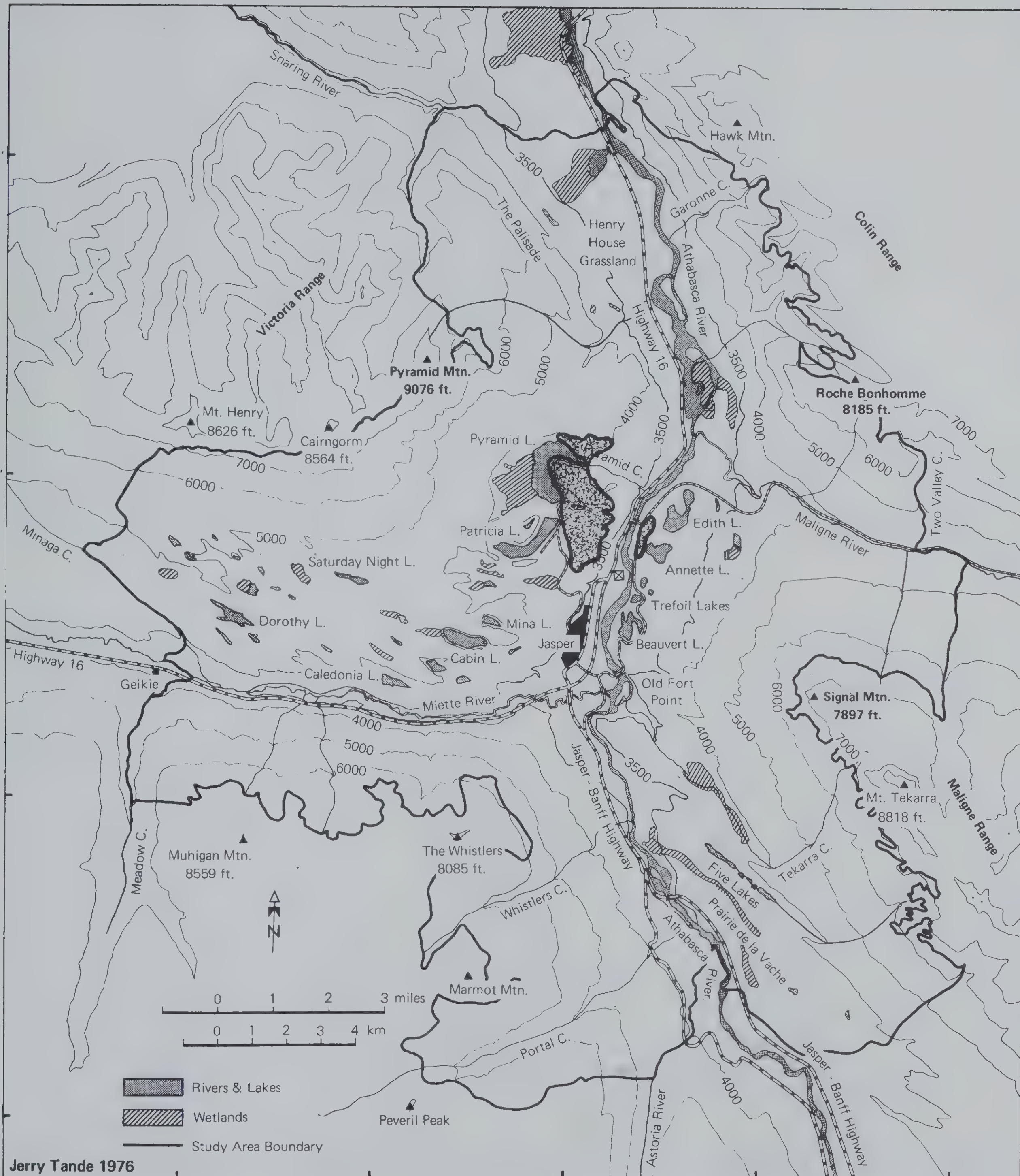


Figure 27. Areal extent of the fires of 1880 around Jasper townsite, J.N.P.

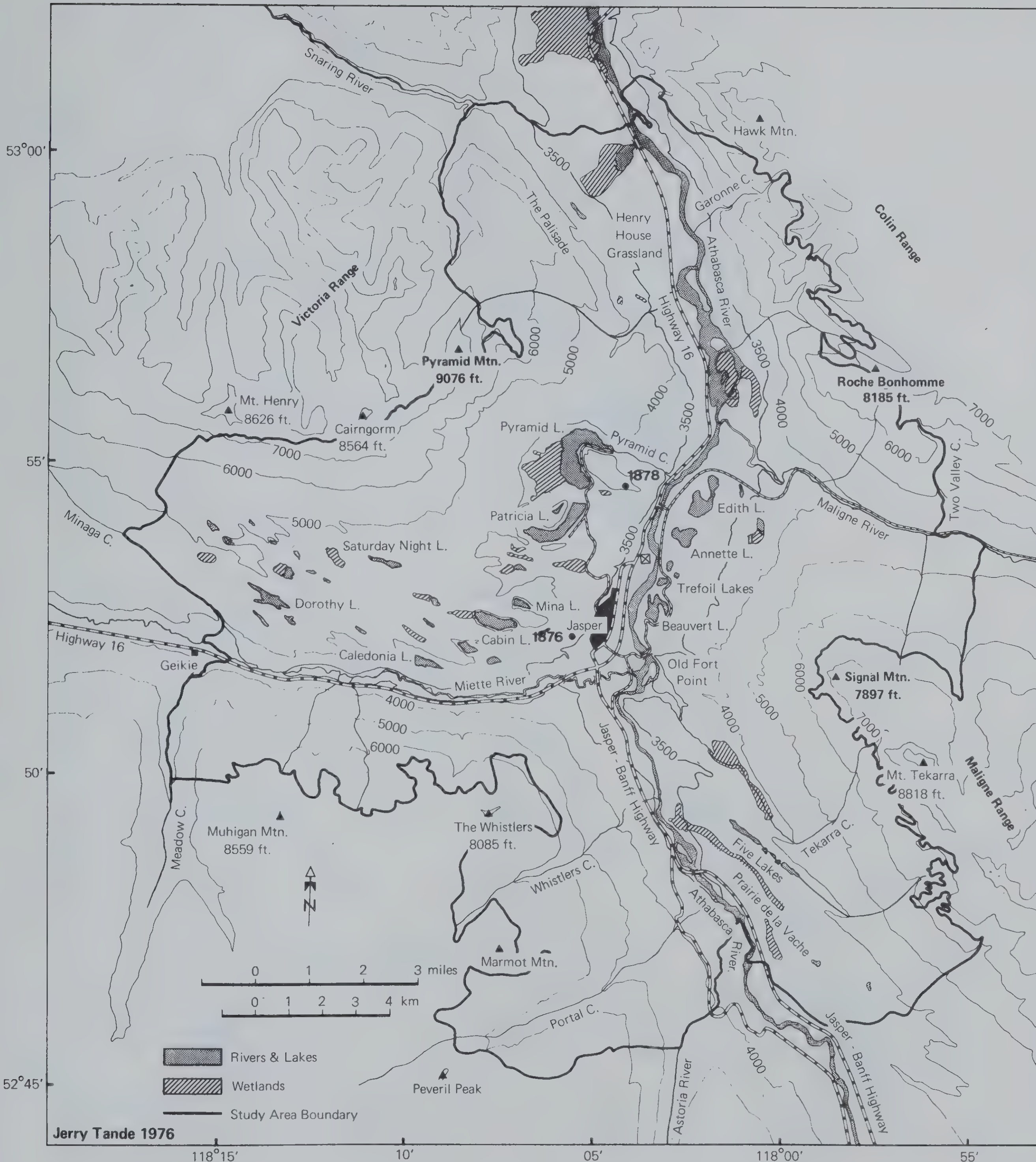


Figure 28. Areal extent of the fires of 1876-1878 around Jasper townsite, J.N.P.

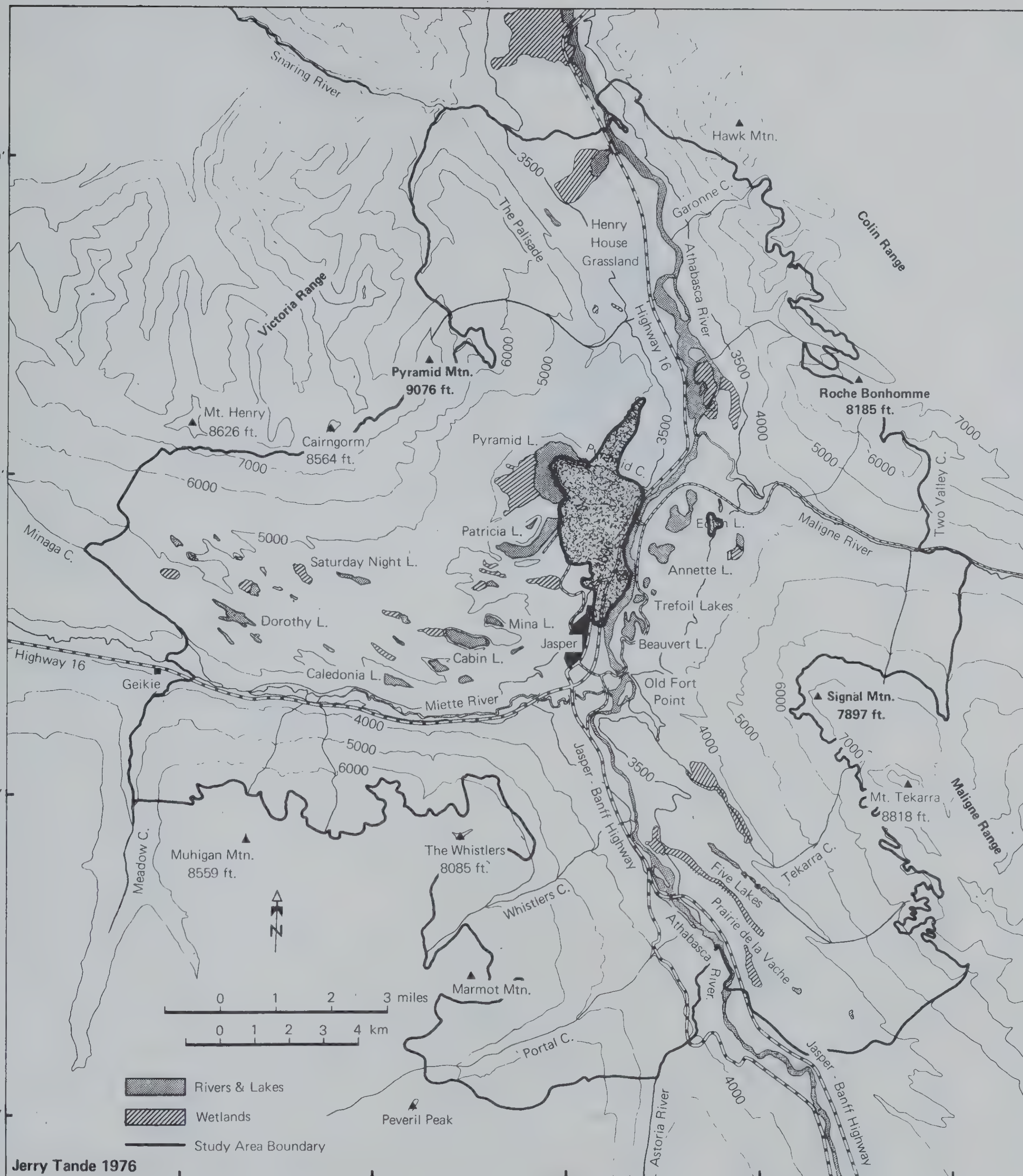


Figure 29. Areal extent of the fires of 1869 around Jasper townsite, J.N.P.

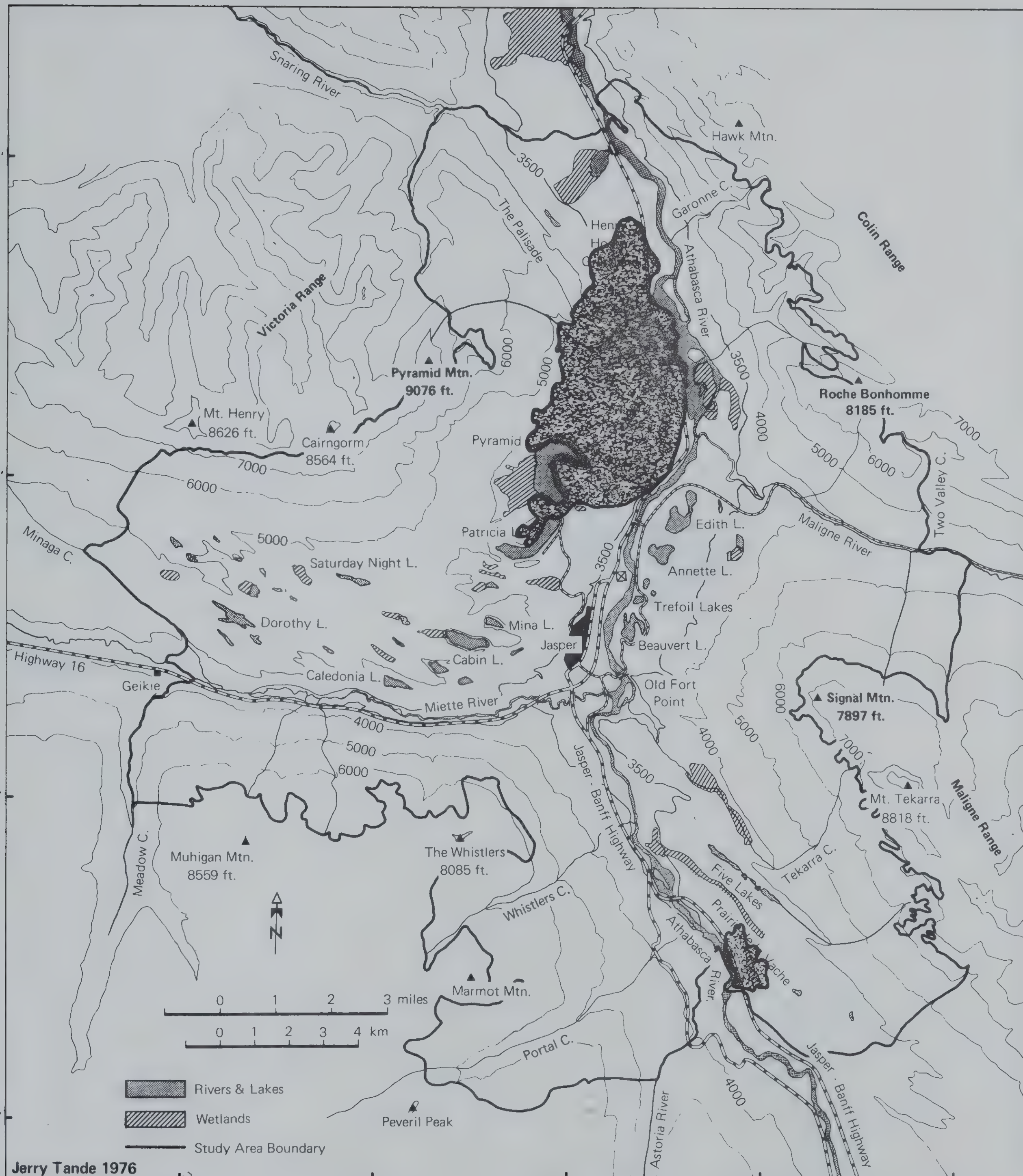


Figure 30. Areal extent of the fires of 1863 around Jasper townsite, J.N.P.

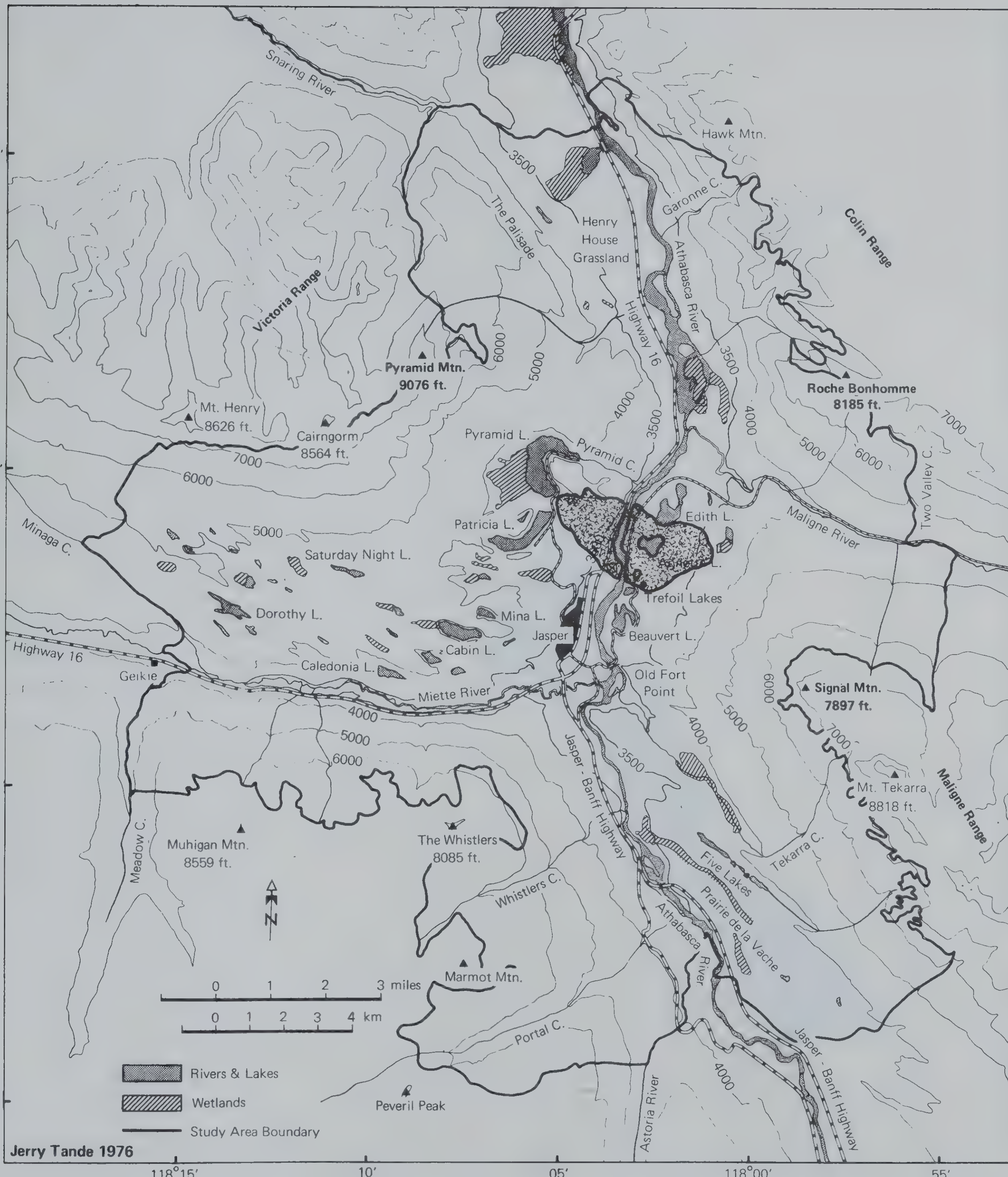


Figure 31. Areal extent of the fires of 1861 around Jasper townsite, J.N.P.

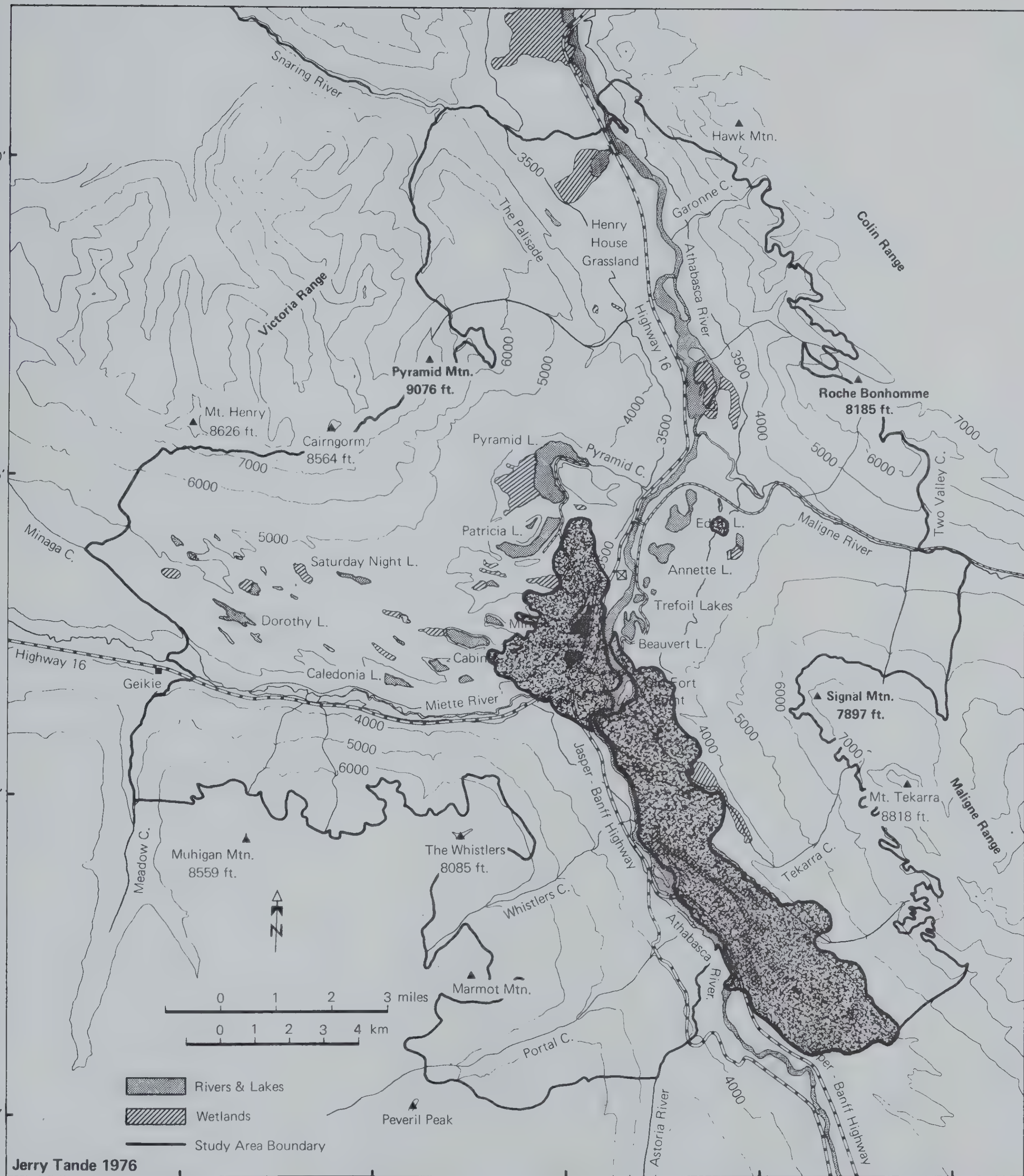


Figure 32. Areal extent of the fires of 1858 around Jasper townsite, J.N.P.

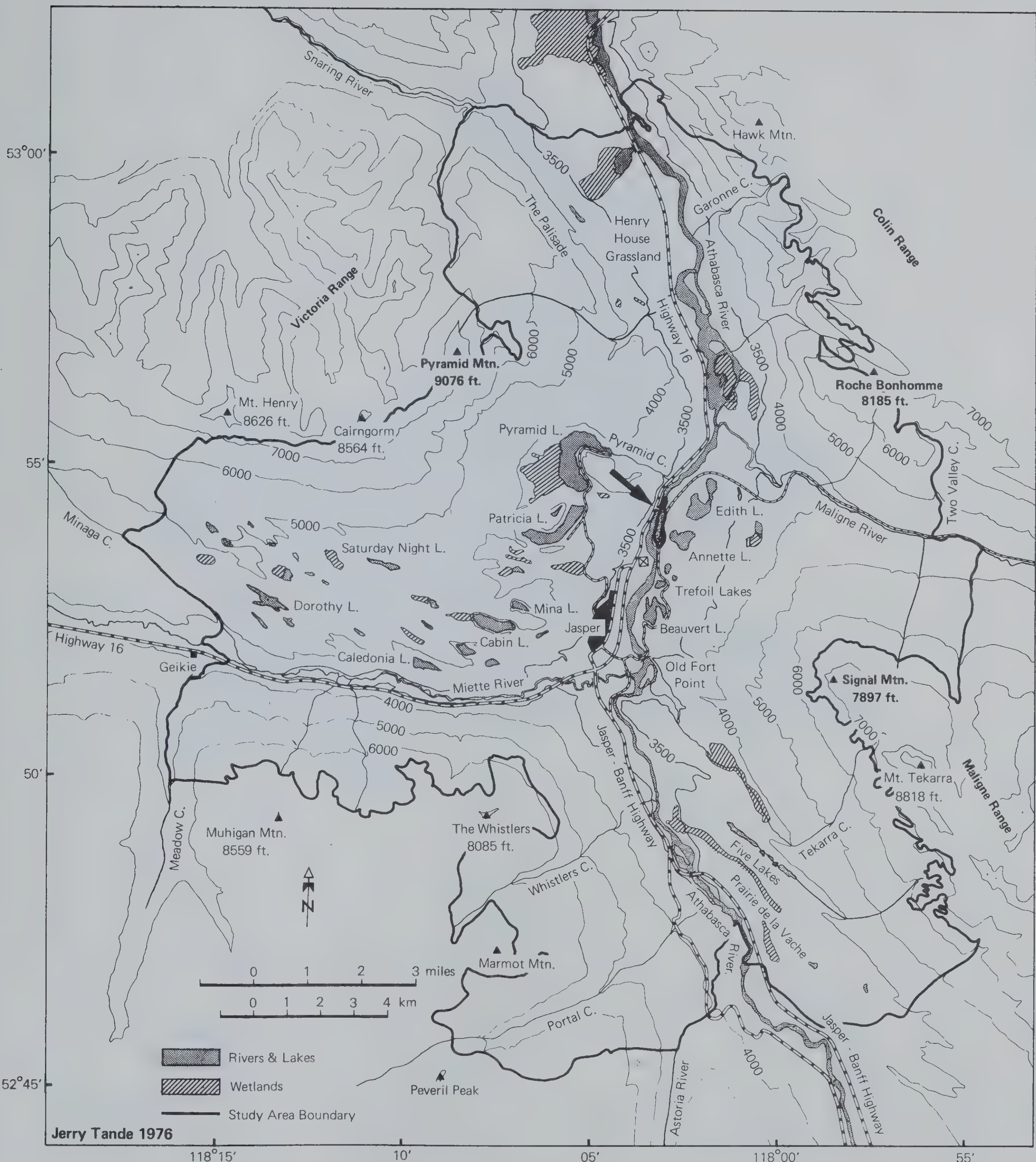


Figure 33. Areal extent of the fires of 1851 around Jasper townsite, J.N.P.

Figure 34. Areal extent of the fires of 1847 around Jasper townsite, J.N.P.

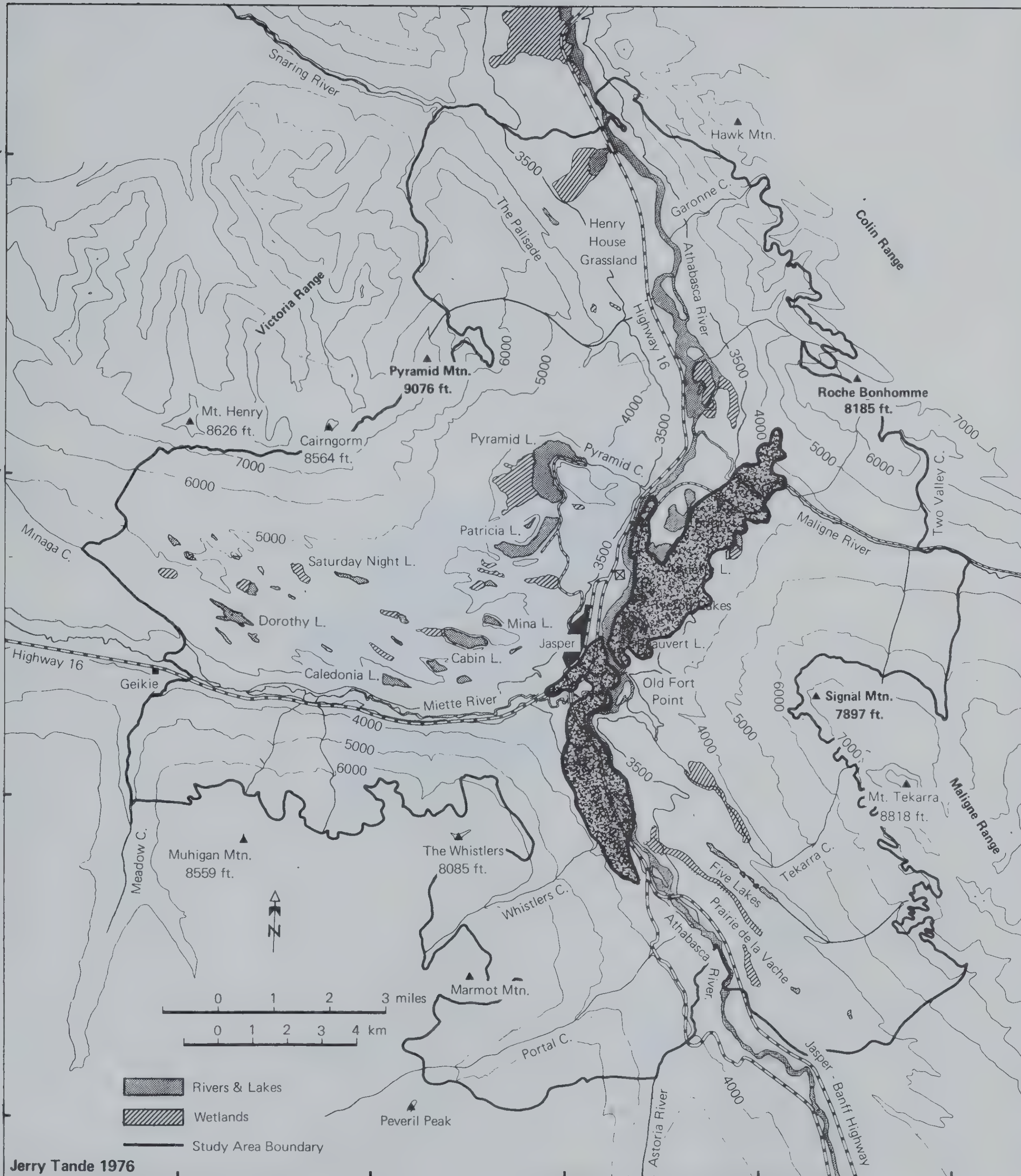


Figure 35. Areal extent of the fires of 1846 around Jasper townsite ,J.N.P.

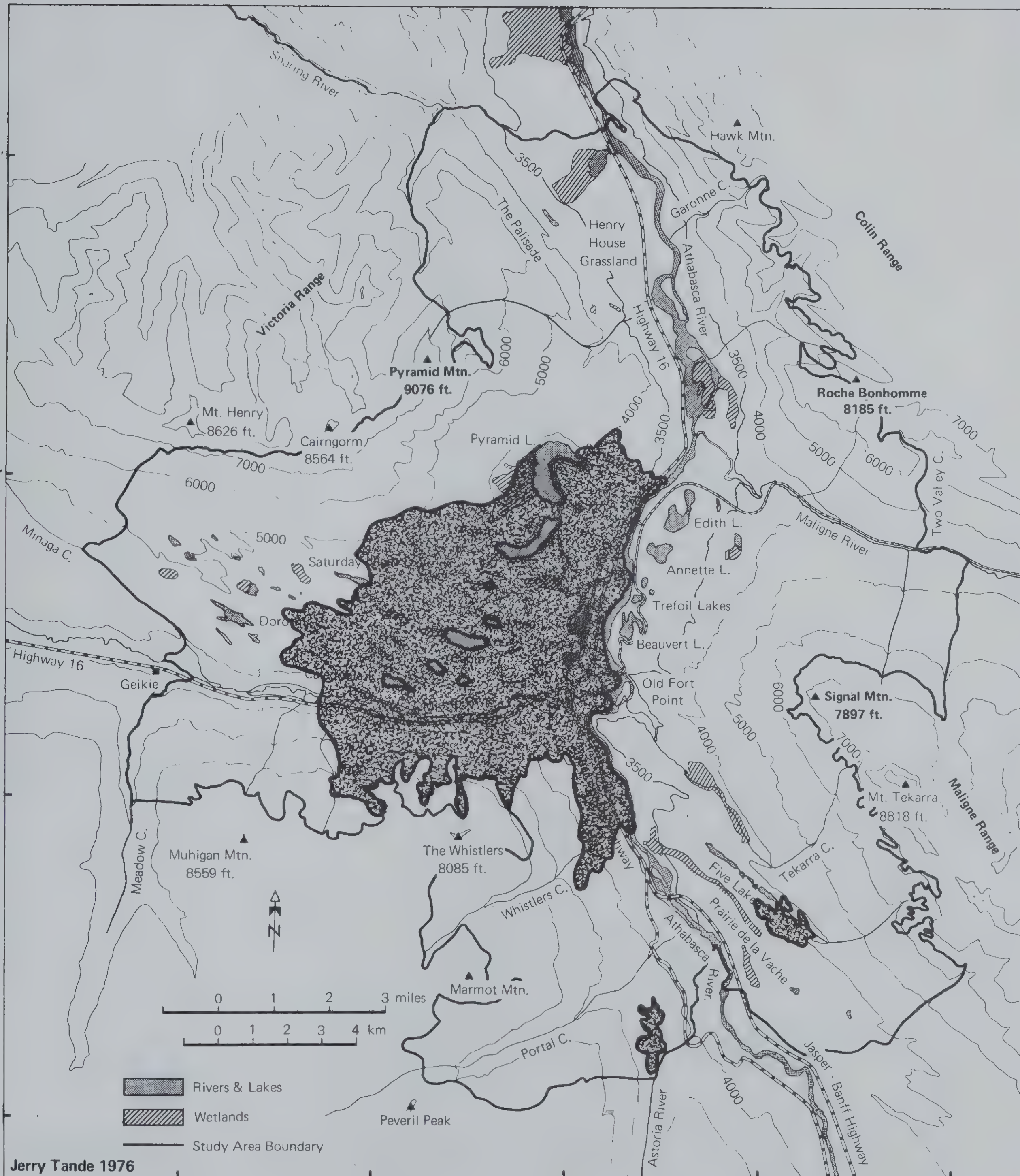


Figure 36. Areal extent of the fires of 1837 around Jasper townsite, J.N.P.

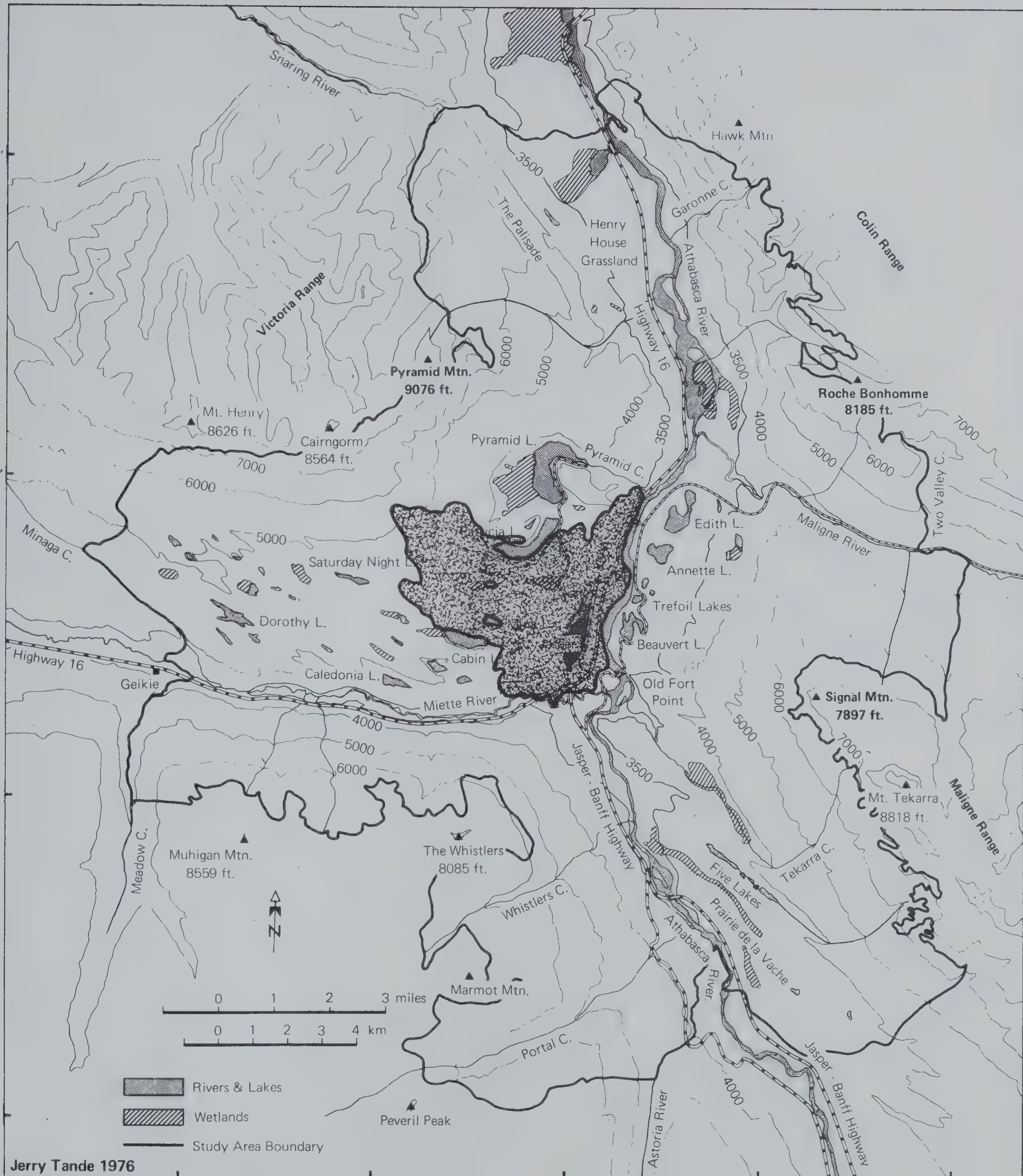


Figure 37. Areal extent of the fires of 1834 around Jasper townsite, J.N.P.

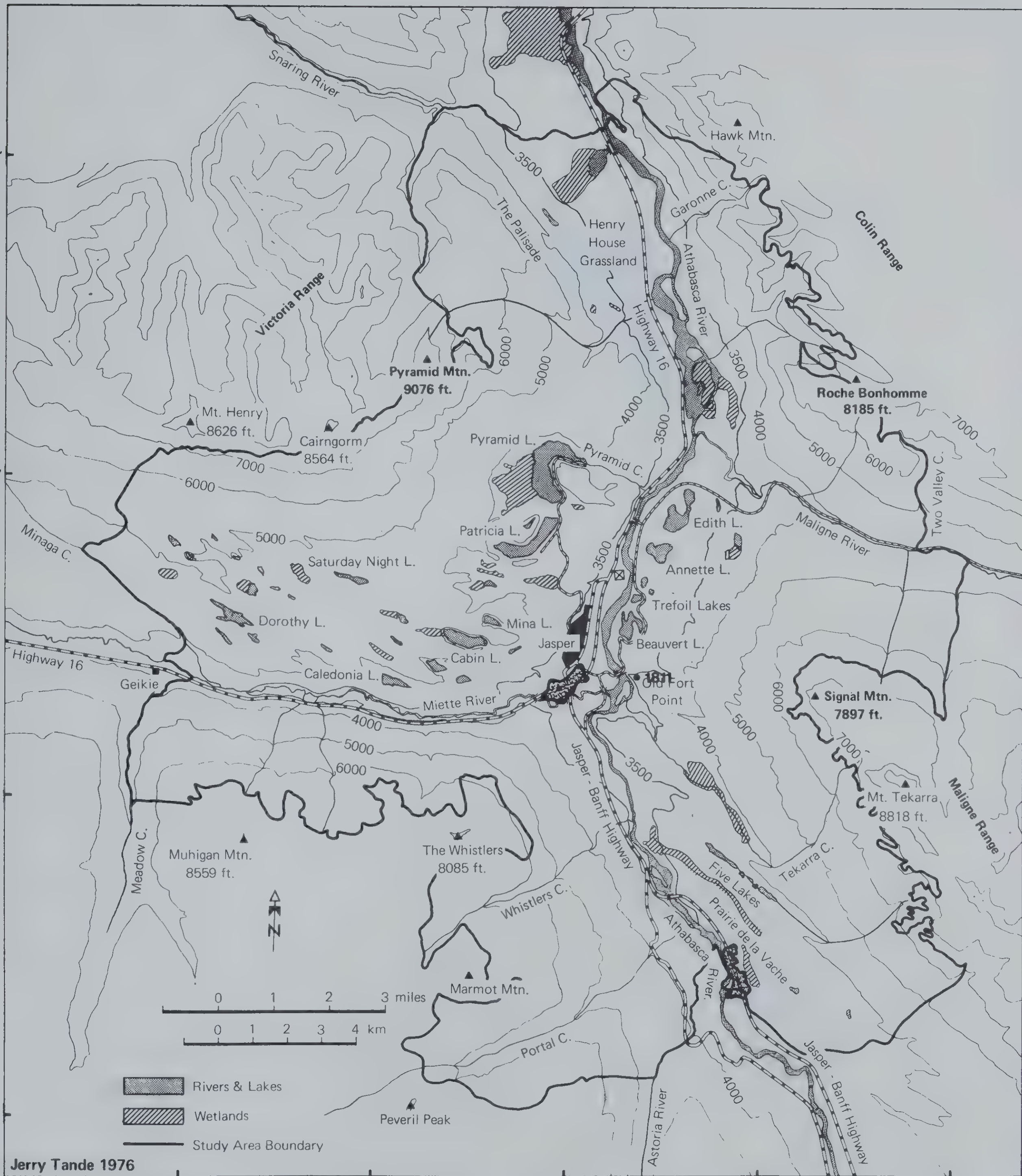


Figure 38. Areal extent of the fires of 1811-1821 around Jasper townsite, J.N.P.

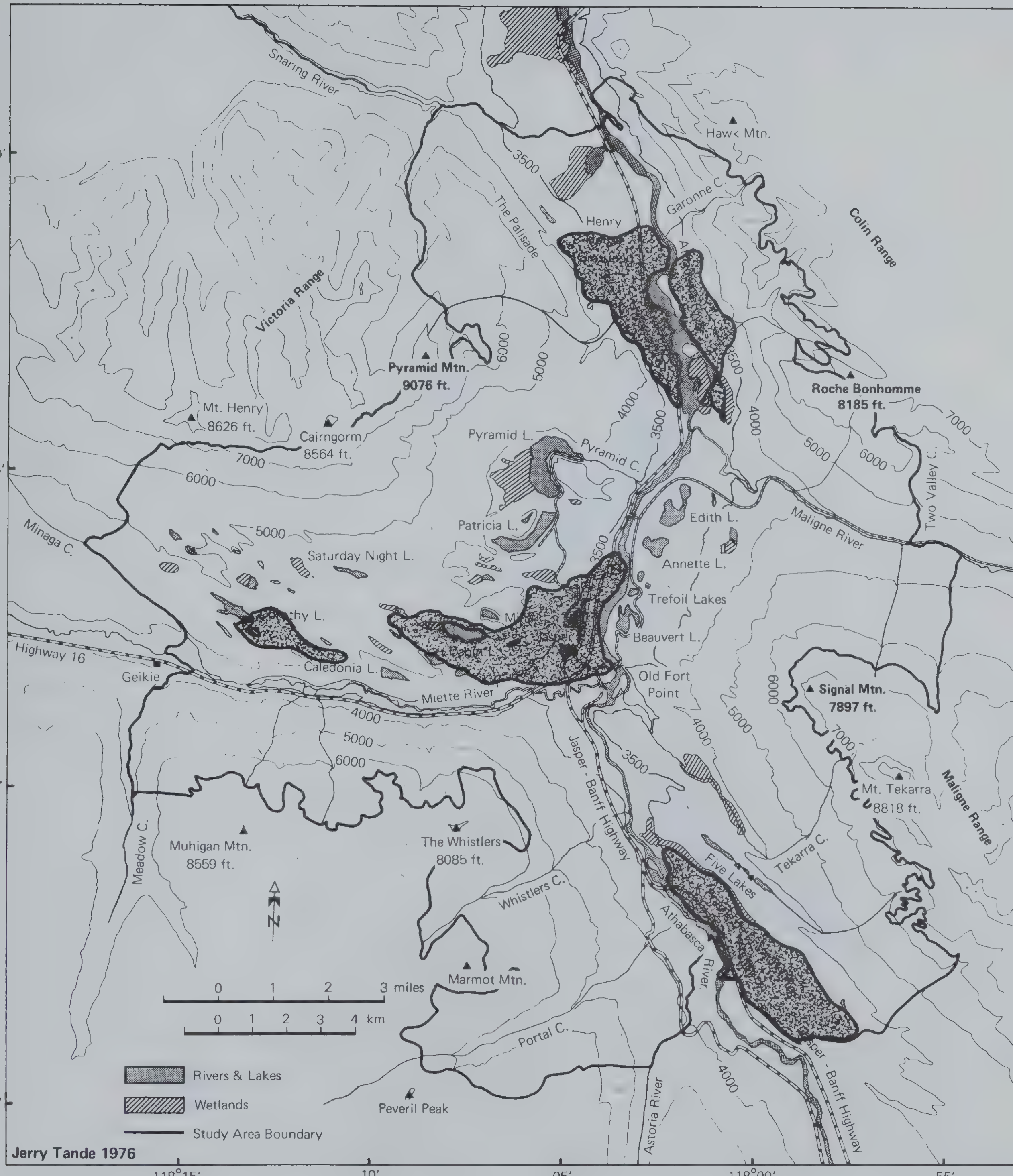


Figure 39. Areal extent of the fires of 1807 around Jasper townsite, J.N.P.

Figure 40. Areal extent of the fires of 1797 around Jasper townsite, J.N.P.

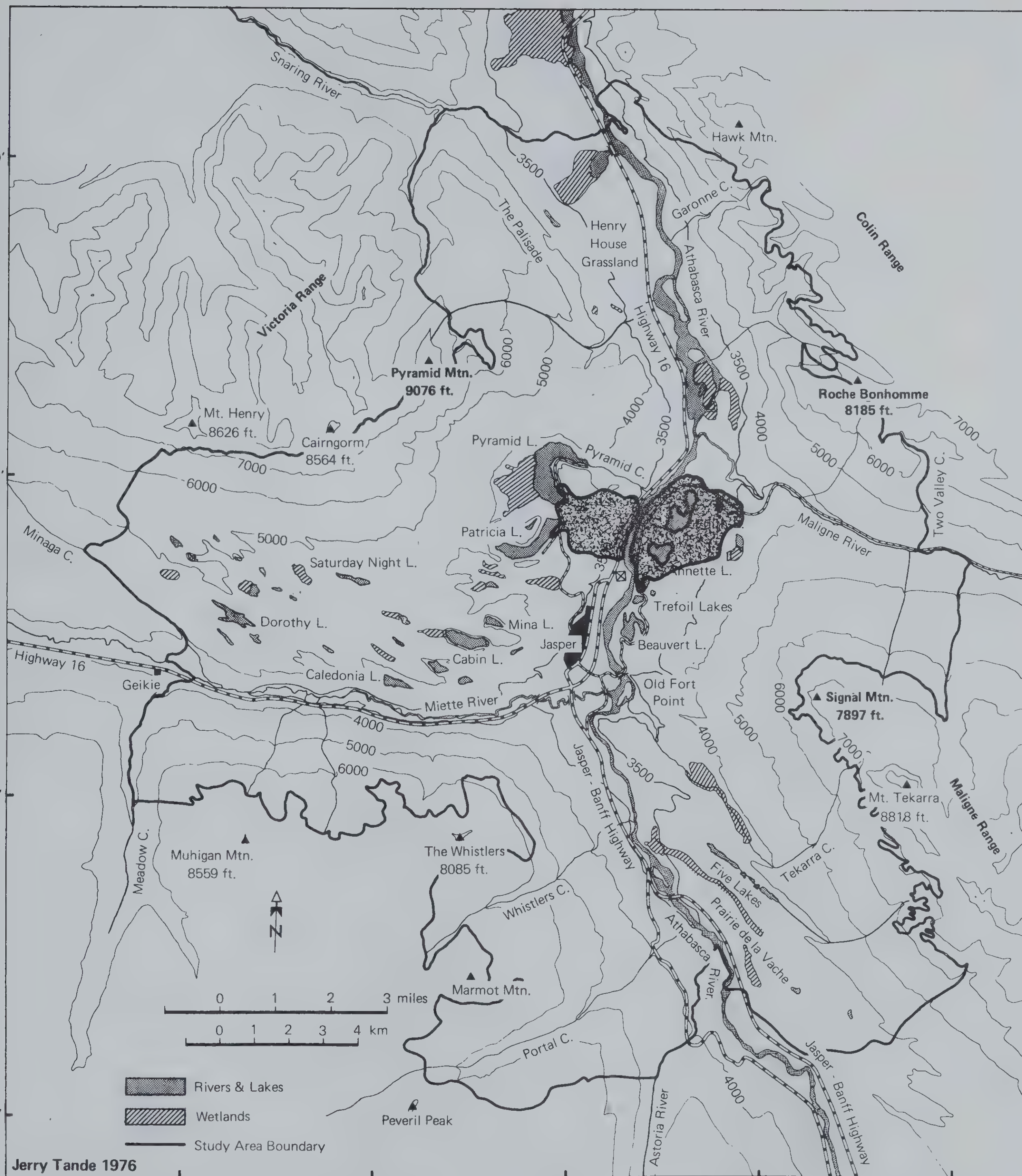


Figure 41. Areal extent of the fires of 1780 around Jasper townsite, J.N.P.

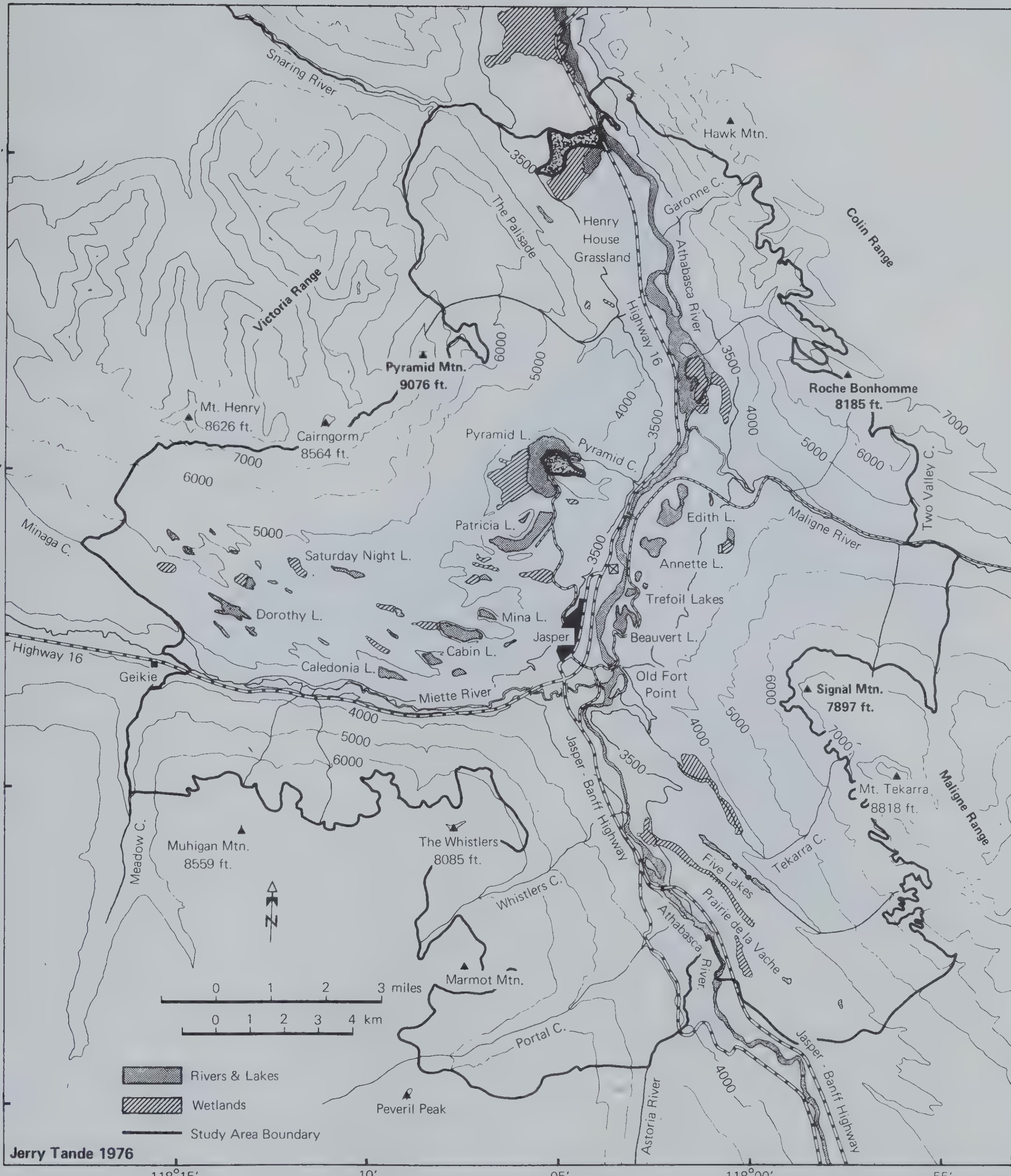


Figure 42. Areal extent of the fires of 1771 around Jasper townsite, J.N.P.

Figure 43. Areal extent of the fires of 1758 around Jasper townsite, J.N.P.

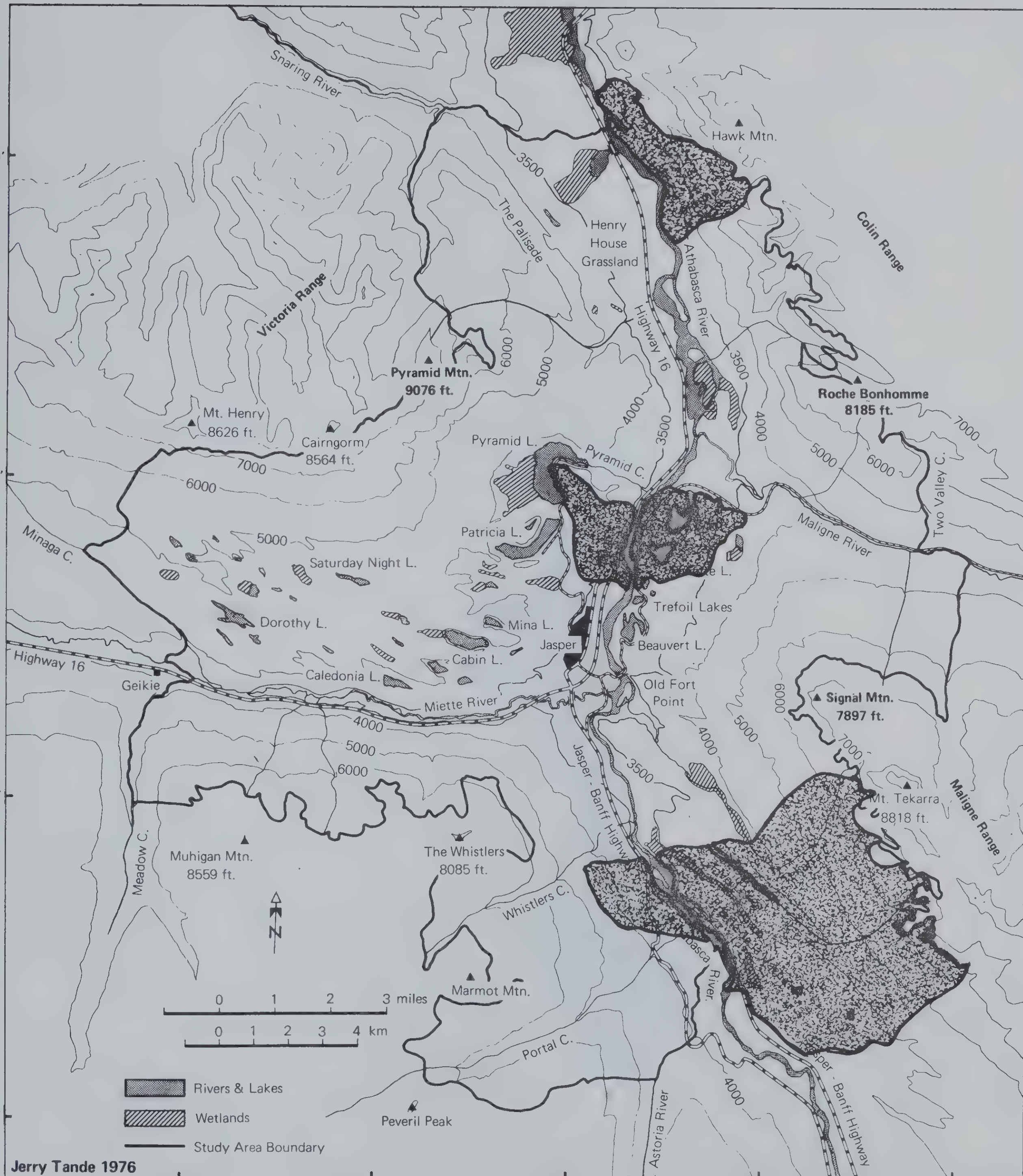


Figure 44. Areal extent of the fires of 1737 around Jasper townsite, J.N.P.

Figure 45. Areal extent of the fires of 1727 around Jasper townsite, J.N.P.

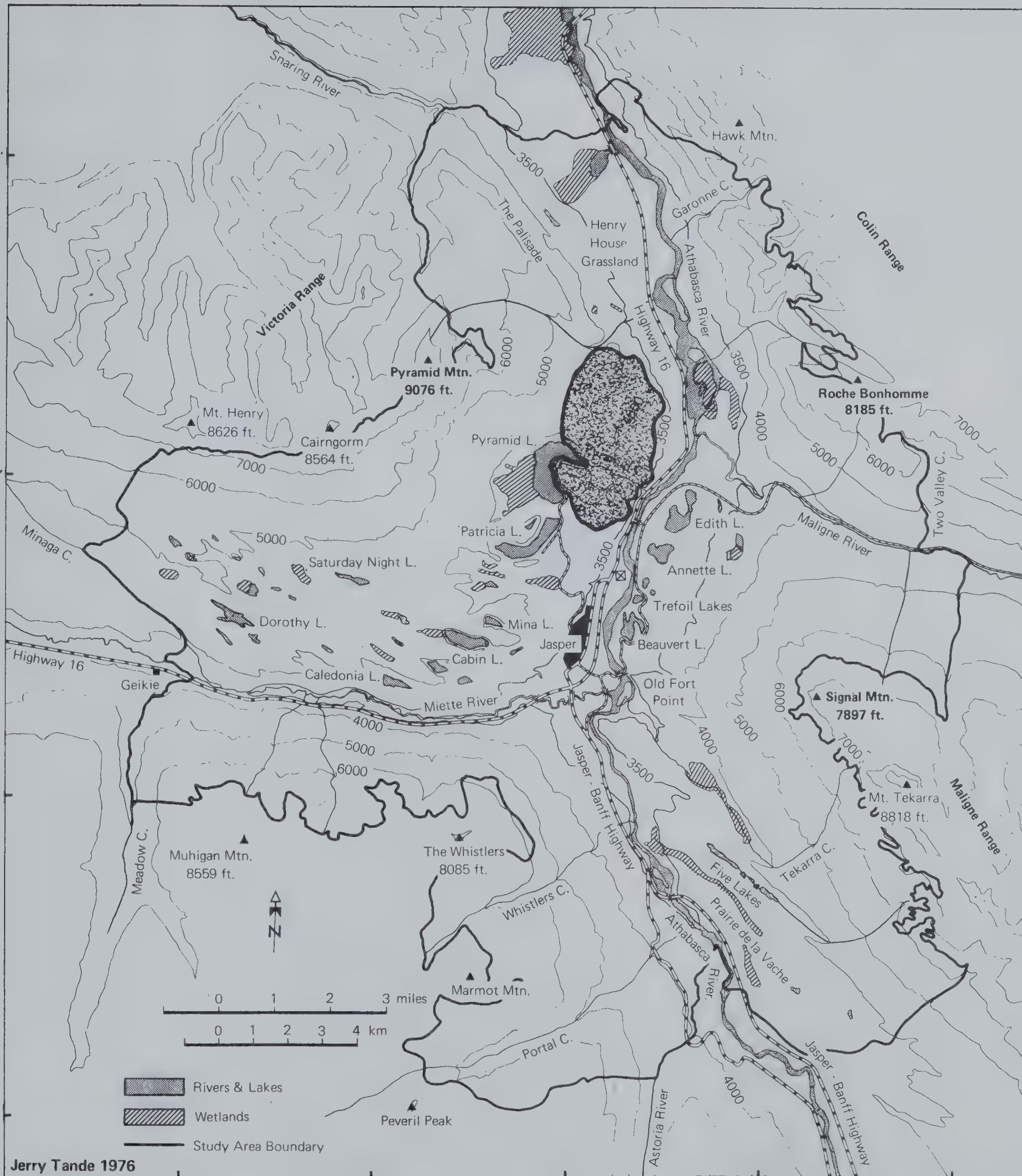


Figure 46. Areal extent of the fires of 1714 around Jasper townsite, J.N.P.

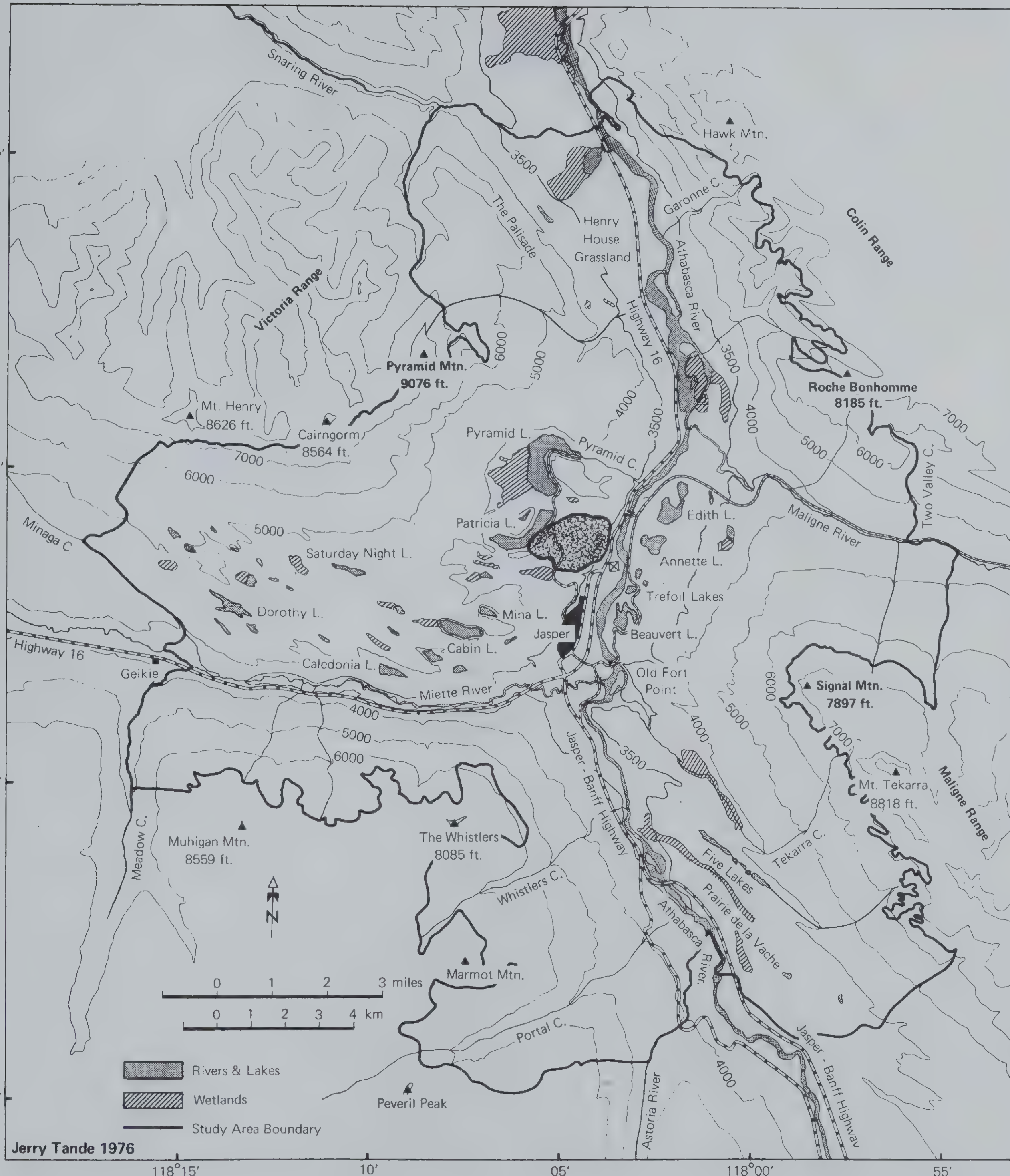


Figure 47. Areal extent of the fires of 1678 around Jasper townsite, J.N.P.

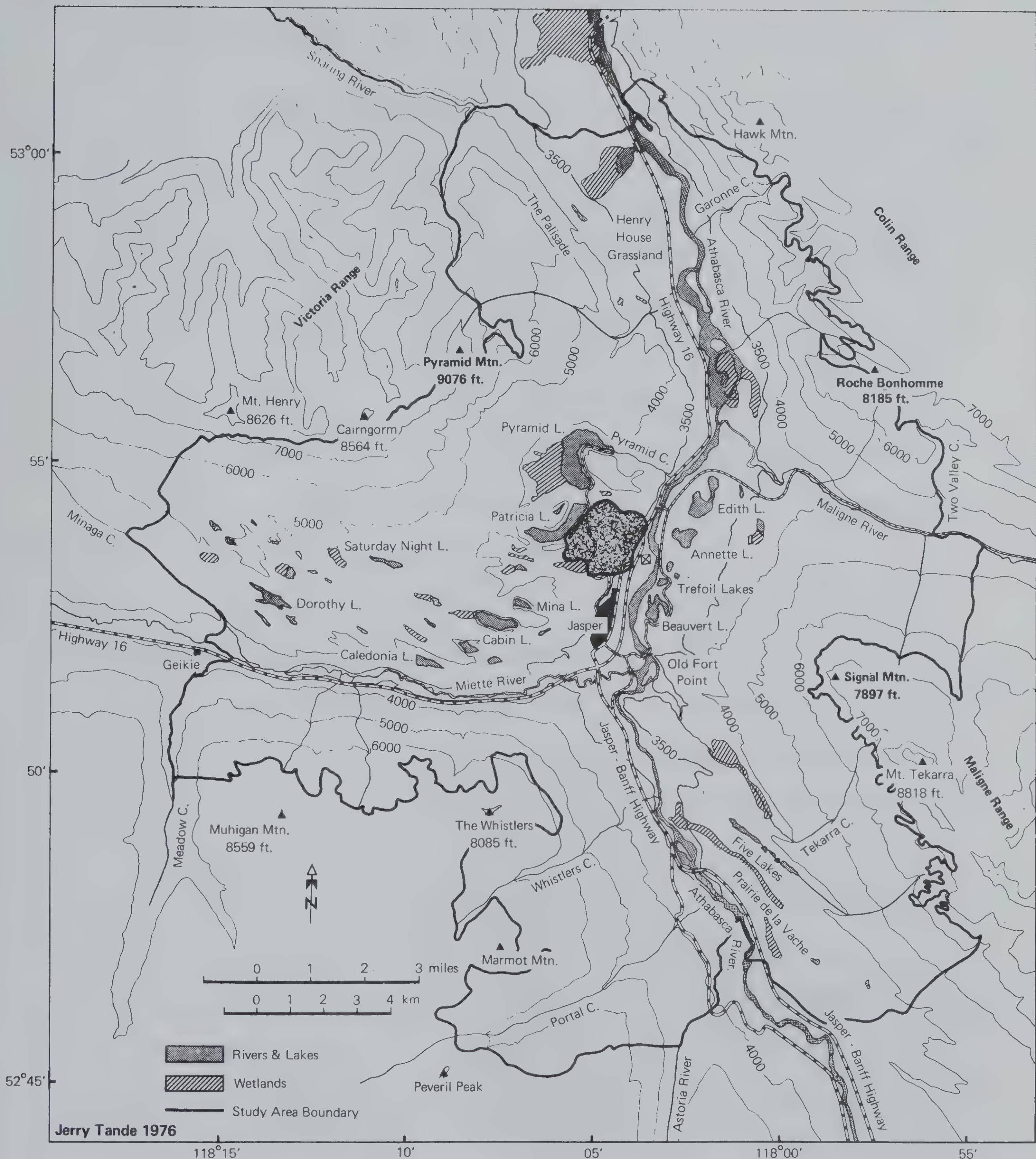


Figure 48. Areal extent of the fires of 1665 around Jasper townsite, J.N.P.

percent of the study area involved are found in Table 2.

Fires of 1904 to 1908. These fires are well documented by fire scar and stand origin data (Figures 14-18). Some margins are still evident on the landscape today. No even-aged stands larger than 45 ha dating from 1904, 1905, 1907 and 1908 were evident. Many scattered fire scars were found which indicated that these fires were of low to medium intensity. They removed the understory and litter from the stands, scarred individual trees and provided for some regeneration throughout their areal extent. Actual fire year boundaries were determined from the limit of fire-scarred trees, stand origin dates and airphoto interpretations of fire margins.

Fires of 1906 were medium to high intensity (Figure 16). Large areas in the southeastern part of the study area have even-aged stands dating from this fire year. The 1906 fires burned less intensely at middle elevations than either in valley bottoms or on upper mid-slopes of the Maligne Range. Pure stands dating from 1906 occupy large areas adjacent to the Athabasca River and nearby slopes between 1350-1650 m (4500-5500 ft). Fire scar evidence in forested areas between these two elevations showed that fire occurred in the stands, but did not stimulate substantial regeneration. No evidence was found connecting outlying areas of occurrence; therefore, they are regarded as individual fires of separate origin or "spot" fires from a larger fire.

Fires of 1892-1903. Fires during this interval were all small, isolated and of low intensity (Figures 18-22). Boundaries of the 1901 and 1902 burns overlapped near the mouth of the Miette River and are based on scar evidence. The fires of 1899 and 1903 were small and not

intense enough to provide for regeneration.

Fires of 1888-1889. These fires were among the most extensive recorded (Figures 23, 24), covering 2.7 and 78.5% of the study area, respectively. The areal extent of the 1888 fires could not be separated with certainty from those of 1889 because of the overlap of stand origin dates. Fire scar dates were used to establish tentative limits of fire extent. It is difficult to determine if isolated areas with evidence for the 1888 fires are connected. Even though many scars of pre-1888 fires were found, none scarred by the 1888 fires were encountered between the areas known to date from 1888. The 1889 fire year accounted for 287 of the 664 fire scar samples; 16 more were from the 1888 fires. Most of the present forest vegetation of the study area dates from these two fire years (Figure 10).

The 1889 fires were of medium to high intensity. Medium intensity fires in low-elevational forests left mixtures of scattered individuals and stands of fire-scarred remnants of the past forest, and associated regeneration. Mid- and high-elevational forests on north- and east-facing slopes were destroyed by high-intensity crown fires. Even-aged forests on the slopes of Signal, Pyramid and Whistlers Mountains all date from this fire year (Figure 12). In many places the subalpine forests were consumed to treeline (Figure 23). The fire margin at the 1680 m (5600 ft) elevation on Signal Mountain is still visible and was the result of these fires. Old 1889 fire margins are also visible in the upper Portal Creek drainage (52°46'N, 118°6'W) on the topographic maps prepared in 1949. However the 1973 airphotos show that the area has regenerated and fire scar dates verified its origin (Figure 12).

Fires of 1851 to 1884. Areal extent of fires before 1888-1889 was more subjectively determined. Fire intensity was almost impossible to quantify because few large stands still showed evidence of dating from any one fire.

Fires of 1851-1884 were moderate in size and restricted to lower and middle elevations of the valleys (Figures 25-33). Larger fires such as those of 1863 were more extensive which suggests, but does not prove, that they were of high intensity (Figures 12 and 30). The 1858 fires were large but restricted to the valley bottoms, indicating low to medium intensity (Figure 32). Others (1876, 1878) were small in extent and of very low intensity. No regeneration attributable to these fires was found (Figure 28).

Fires of 1846-47. In 1847, at least 52.3% of the study area was burned (Figure 34). The fire may have been more extensive, but the data base decreases with time (Figure 11). The 1847 fires behaved much like those of 1889, *i.e.* they were of moderate to high intensity, and burned hotter at higher elevations. Large areas of the Miette and lower Athabasca River valleys postdate this fire year. Also, subalpine lodgepole pine forests on the south-facing slopes of the Miette River valley originated after these fires (Figure 12). Fire margins on Pyramid Mountain and the Pallisade still visible today are the result of these fires. The 1889 fires burned up to, and occasionally through this older fire margin (Figure 12). Many doubly-scarred trees along the fire margin bear this out. There is no evidence to indicate that the 1847 fires burned farther east up the Maligne or south up the Athabasca River valleys than is indicated by Figure 34.

Fires in 1846 were essentially restricted to the valley bottom (Figure 35) in contrast to those of 1847. The locations of the numerous fire-scar dates (18) indicated that the fires stopped at natural fire breaks such as rivers and lakes. Absolute boundaries would be difficult to determine if one considered only stand origin dates, since much of the vegetation of the study area originated after the big 1847 fire year. The scar evidence, however, suggested that the fires of 1846 did not exceed the boundaries illustrated (Figure 35). Stand origin dates and fire scar evidence from areas not subsequently burned in 1847 indicated that the burns of 1846 were of low to medium intensity.

Fires of 1811 to 1837. The combination of two large fire years 1889 and 1847 further masks the areal extent and severity of earlier fires. Those of 1837 (Figure 36) were also extensive and burned into north-facing subalpine forests much like the fires of 1889 and 1847. This indicates a fire of medium to high intensity that was probably more extensive than illustrated. Based on this observation and the paths of prevailing winds, outlying areas of the 1837 burn year in the upper Athabasca River valley may have been connected. This is speculation, as no evidence for this fire was found between the areas concerned.

The 1811-1834 fires are well documented by fire scar evidence (Figures 37-38). Like burns of 1851-1884, they were restricted to the valley bottoms and lower slopes. Fires of 1834 covered a large area and were probably of low to medium intensity since many of the scar dates documenting them were from individuals scarred by earlier fires

and would likely not survive an intense fire. Fires of 1811 and 1834 were probably small and of low intensity since few scars documented these years and no stands originating after them were found.

Fires of 1771 to 1810. Areal extents of fires before 1811 are approximate. Those of 1797 and 1807 (Figures 39-40) are similar to 1834, consisting of isolated burns having separate areas of evidence which may have been connected. Their extent suggests moderately intense fires. Fires of 1780 and 1771 were restricted to the valley bottoms and were probably of low intensity (Figures 41-42).

Fires of 1758. The earliest large-scale fire year revealed by the fire scar and stand origin data was 1758. These fires covered at least 50.9% of the study area and were of medium to high intensity (Figure 43). Like the fires of 1847 and 1889, they burned well into the subalpine forests. Slopes of the Colin Range and Signal Mountain have large areas that date from this fire year. The best remaining example of this remnant forest is found on the south-facing slope of Roche Bonhomme in the Maligne River valley (Figures 12 and 49).

Fires Before 1758. The combination of three large medium to high intensity fire years (1758, 1847, 1889), interspersed with many low to medium intensity fires, has erased much of the evidence for earlier fires. No fires were recorded in the lodgepole pine fire-scar record before 1758. Scar dates from Douglas-fir were used to carry the fire chronology from 1758 to 1665 (Figures 44-48). Thirty-two stand origin dates were used to plot approximate areal extents of the 1737 and 1727 fires (Figures 44- 45), and 13 Douglas-fir stand origin dates were used to plot approximate boundaries of pre-1727 fires.

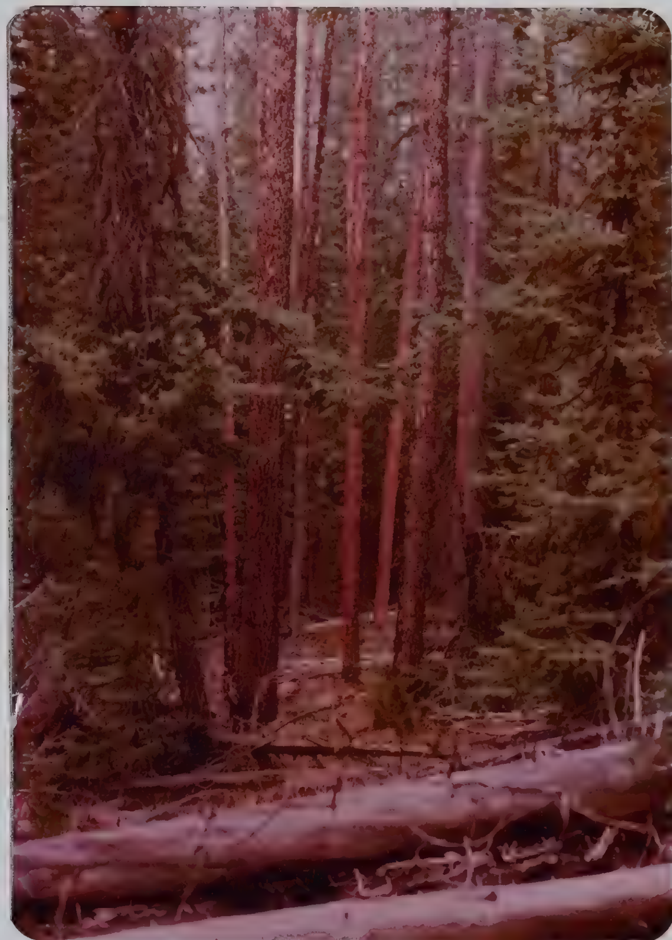


Figure 49. Lodgepole pine forest of 1758 origin on the south-facing slopes of Roche Bonhomme, Maligne River valley. Engelmann spruce has entered the pine canopy and subalpine fir is present in the understory (10 June 1975).

Burn Direction

Burn directions were difficult to infer from the fire scars, especially for the larger fires. Fire-generated winds and complex mountain topography create very complicated patterns of burn direction. If a tree is scarred by a second fire, it is generally on the same side of the tree as the first, since fire susceptibility is increased by resin or old bark accumulations around the previous scar. Consequently the direction of the earliest fire can potentially be obtained, but later fires are probably questionable.

Fire scars generally followed the pattern of prevailing winds of dry weather (Figure 2). Pattern of fire scar directions indicated that most fires burned down the Miette and deflected in all directions off Signal Mountain. Fires such as 1905 and 1863 fit this pattern (Figures 17, 30). The 1906 fire was well documented and burned south up the Athabasca valley spreading upslope. The shape of the latter fire conforms to the direction inferred from scar observations, being smallest to the north and widening as it spread southward (Figure 16).

Larger fires were more complex. The 1758 fire conformed to the 1905 and 1863 pattern (Figure 43). The 1889 fire, however, was very complex and no pattern could be discerned. The influence of winds down the Miette and up the Athabasca suggested that more than one fire was responsible for the total extent of the 1889 burns (Figure 23).

Mean Fire Return Interval

Mean fire return interval (MFRI) is the average number of years between consecutive fires. It is defined by the formula:

$$MFRI = \frac{\Sigma(i_2 - i_1)}{N}$$

where (i_2-i_1) = interval between any two fire years

N = number of intervals identified for an area (number of fires -1).

Intervals between all documented fire years, and between all major fires are found in Table 2. They provide a framework of fire periodicity for the whole study area. The true MFRI is probably shorter because fire evidence is lost with time.

A fire has occurred somewhere in the study area on an average of once every 4.4 years during the period of record 1665 to 1975. For the 248 yr period (1665-1913) before active fire suppression, 46 fires occurred with a MFRI of 5.5 yrs. The periodicity of major fires was, of course, somewhat longer. Those covering more than 1.2% (500 ha) of the area had a MFRI of 8.4 ranging from 1 to 27 yrs.

It is also useful to consider the longer intervals of progressively larger fires such as those covering more than 2, 6, 12 or 50% of the study area (Table 3). Fires covering more than 50% of the valleys had a MFRI of 65.5, ranging from 42 to 89 yrs. The fires of 1889 covered 78.5%; the 1847 and 1758 fires covered at least 52.3 and 50.9% of the valleys, respectively. Thus, for the last 310 yrs, the study area has experienced recurring fires of widely differing sizes with larger fires occurring at much longer intervals (Figure 8).

These "regional" MFRI's apply to the study area as a whole, and should not be confused with those for smaller unit areas within it. Since very few fires burned the entire study area, means on an areal or elevational basis are more valid and useful for future scientific

TABLE 3. Mean fire return intervals (MFRI) for the study area around Jasper townsite, Jasper National Park.

Data base	Number of fires	Mean fire return interval (yrs)	Range (Yrs)
All fires	72	4.4	1-36
All fires before 1910	46	5.5	1-36
Fires burning $\geq 5.00\ km^2$ (1.2% of the Area)*	24	8.4	1-27
Fires burning $\geq 10.00\ km^2$ (2.4% of the Area)	17	11.4	1-27
Fires burning $\geq 25.00\ km^2$ (6% of the Area)	10	19.9	10-39
Fires burning $\geq 50.00\ km^2$ (12% of the Area)	6	32.4	10-79
Fires burning $\geq 100.00\ km^2$ (24% of the Area) or $\geq 216.00\ km^2$ (50% of the Area)	3	65.5	42-89

*Fires burning more than 500 ha are termed "Major Fires" in this study.

investigations, for management, and for interpretive purposes.

Fire return intervals for different plant community types on an areal and elevational basis are provided in Table 4. Sixteen 50 ha blocks of major vegetation types were chosen for comparative purposes. Only three grassland-savannas and four Douglas-fir forests in the area meet the 50 ha qualification. Five areas of lodgepole pine were selected since this is the dominant forest type in the valley. One pine area was chosen from each of the four extensions of the study area (N, S, E, W), and one block north of Jasper townsite was selected to represent the centre of the study area. Centres of the 50 ha blocks are south of their respective landmark (*e.g.*, "Five Lakes lodgepole pine block" is centred south of Five Lakes, its northern border on the lake-shore).

Areal extent of individual fires is very important in determining MFRI. The MFRIs are at least three times longer for any given area within a given community type, than the MFRI for the entire study area (Table 4).

MFRIs varied from block to block within plant community types but were not significantly different at $P < 0.05$ (Analysis of variance, F-statistic, Table 4). Using Duncan's New Multiple Range test, no statistical differences in fire periodicity were found between lodgepole pine, grassland-savanna, and Douglas-fir; however, all three low-elevation types had significantly shorter MFRIs than the subalpine forests ($P < 0.05$).

Fire Frequency

The number of fires varied between different parts of the study

TABLE 4. Mean fire return intervals (MFRI) in 50 ha blocks of four community types in the study area around Jasper townsite, Jasper National Park.

Vegetation Type and Location	Number of fires	Mean Return Interval (yrs)	Range (yrs)	F-Statistic for within-type variance ($P < 0.01$)	Mean number of fires	Mean Return Interval for Type (yrs)
All fires	72	4.4	1-36			
All fires before 1913	46	5.5	1-36			
Major fires before 1913*	24	8.4	1-36			
Lodgepole pine Forests				2.30	8	26.8
Around Townsite	16	12.0	1-31			
Five Lakes	6	22.7	7-39			
Maligne Canyon	7	25.0	1-88			
Dorothy Lake	6	29.4	10-49			
Snaring River	4	44.7	16-76			
Douglas-fir Forests				1.05	11	17.6
Around Pyramid L.	15	13.6	1-40			
Annette L.	12	16.3	1-66			
Cabin L.	10	16.3	3-39			
Five Lakes	8	24.1	10-39			

TABLE 4. Continued.

Vegetation Type and Location	Number of fires	Mean Return Interval (yrs)	Range (yrs)	F-Statistic for within-type variance ($P < 0.01$)	Mean number of fires	Mean Return Interval for Type (yrs)
Grassland-Savanna				0.07	9	20.6
Around Prairie de la Vache	10	18.8	10-39			
Fish Hatchery	9	21.2	1-67			
Henry House	7	21.7	1-40			
Subalpine Forests				1.44	4	74.0
Cairngorm-Pyramid Mtns.	5	33.0	3-76			
Signal-Amber Mtns.	5	42.3	17-89			
Whistlers-Marmot Mtns.	3	89.5	17-16			
Signal-Excelsior Mtns.	2	131.0	--			

*Major fires are fires burning more than 500 ha (1.2% of the area).

area (column 1, Table 4). However, fire frequency between blocks of the broadly defined community types was not significantly different at P <0.05 for Douglas-fir, grassland-savanna and subalpine forest (Table 5). They were significantly different within the lodgepole pine type, but when the large number of fires near Jasper townsite was removed from calculations, there was no significant difference in number of fires.

The mean number of fires for lodgepole pine, Douglas-fir and grassland-savanna are similar (8, 11, 9 respectively) and show a marked difference from the mean number of fires for the subalpine (4). Chi-square values showed similar trends but were not significantly different at P <0.05 (Table 6).

To test the hypothesis that the number of fires decreased with increasing elevation, four transects were run on the fire year maps from the 1050 m (3500 ft) contour interval north of Jasper townsite to treeline near the summits of Pyramid, Roche Bonhomme, Tekarra and Whistlers Mountains (Figure 50). Total number of fires was tallied along these transects at 150 m (500 ft) intervals. In each transect there was a significant negative correlation between number of fires and elevation (P <0.05, Table 7).

Numbers of fires on different aspects were also tabulated to test the hypothesis that more fires occurred on south- and west-facing slopes than on north- and east-facing slopes. Totals were obtained for flanks of mountain ranges above a point where the elevational gradient was more than 300 m/km. The number of fires on N-NE slopes was smaller than on S-SW slopes, but the difference was not significant at P <0.05 (Table 8). This may be the result of the small sample size of fires.

TABLE 5. Chi-square test for significant differences in the number of fires between 50 ha blocks within four broadly defined community types ($P < 0.05$) in the Jasper townsite study area.

Community type	n(number of blocks)	χ^2	$P < 0.05$
Lodgepole pine	5	11.39 0.43*	9.48
Douglas-fir	4	2.37	7.81
Grassland-savanna	3	0.53	5.99
Subalpine spruce-fir	4	0.13	7.81

*With Jasper townsite block data removed from calculations.

TABLE 6. Chi-square values for differences in fire frequency between four broadly defined community types in the Jasper townsite study area ($P < 0.05 = 3.84$).

	Subalpine spruce-fir	Grassland-Savanna	Douglas-fir	Lodgepole pine
Lodgepole pine	1.33	0.06	0.47	
Douglas-fir	3.27	0.26		
Grassland-savanna	1.92			
Subalpine spruce-fir				

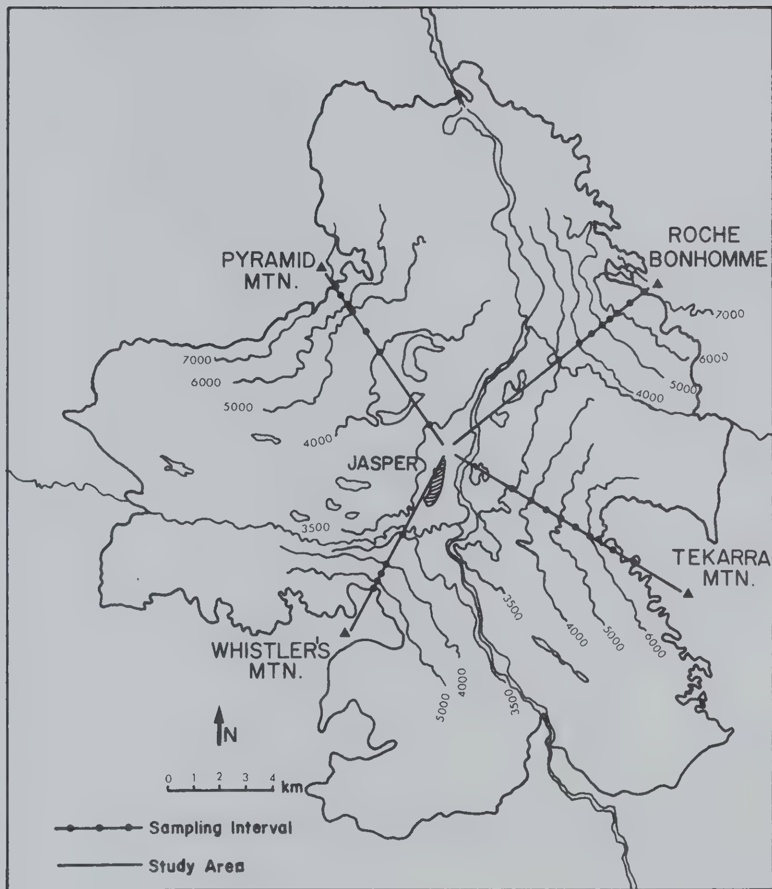


Figure 50. Location of transects at 150 m (500 ft) contour intervals for determination of fire frequency along an elevational gradient.

TABLE 7. Spearman's correlation coefficients for changes in number of fires at 150 m (500 ft) elevational intervals along five transects originating north of Jasper townsite.

	Number of Fires				
Elevation feet (m)	Jasper - Pyramid Mtn.	Jasper - Roche Bonhomme	Jasper - Tekarra Mtn.	Jasper - Whistlers Mtn.	Total
3500 (1050)	5	6	8	4	23
4000 (1200)	4	4	3	2	13
4500 (1350)	3	2	3	2	10
5000 (1500)	2	2	3	1	8
5500 (1650)	2	2	3	1	8
6000 (1800)	2	2	2		6
6500 (1950)	2	2	3		7
7000 (2100)	1	1	1		3
Spearman's rank order correlation coefficent					
"r"	-0.906	-0.802	-0.668	-0.894	-.954

TABLE 8. Chi-square test for significant differences between number of fires on N-NE- and S-SW-facing slopes in the study area around Jasper townsite ($P < 0.05 = 3.84$).

Area	Aspect	Number of fires	Area	Aspect	Number of fires	χ^2
Whistlers - Marmot Mtns.	NE	8	Signal - Amber Mtns.	SW	11	0.47
The Pallisade	NE	6	Morro-Bonhomme Mtns.	SW	8	0.29
Signal - Excelsior Mtns.	N	2	Bonhomme-Grisette Mtns.	S	5	1.29
Muhigan - Whistlers Mtns.	N	5	Henry-Cairngorm Mtns.	S	10	1.67
Total		21			34	3.07

Only a very few fires were intense enough to burn into higher elevation forests during the period of record due to complex moisture gradients and associated organic matter accumulations.

DISCUSSION

Fire and Cultural History

Archaeological evidence indicates that man has been a part of the Jasper environment for at least the last 10,000 yrs (Anderson and Reeves 1975). The Athabasca and Miette River valleys have been major corridors through the mountains for all of recorded history and were probably used earlier. Because man was an integral part of the environment, his role must be borne in mind when considering the natural fire regime.

Byrne (1968) and MacKenzie (1973) have reviewed the role of man in landscape change in Banff and Waterton Lakes National Parks. It is left to the anthropologists to determine the relative importance of early native peoples and European man as causes of past fires in the Jasper study area. Of significance to this study, however, are the following interpretations of fire history data and cultural history.

The human history of the Jasper National Park region has been divided into six major periods (Table 1, page 21). The total number of fires by these historical periods increased from past to present, with the exception of the Railroad Period when the number of fires was less (Table 9). Mean fire return interval (MFRI) shortened from 16.5 yrs in the Pre-European Period to 1.3 yrs during the Settlement Period. This increase in fire periodicity may be related to increased human activity with time, but is partially the result of erasure of fire sign by subsequent fires. With the establishment of an active fire suppression campaign during the Park Period, fire frequency in the study

TABLE 9. Mean fire return intervals and burned areas for cultural history periods in the Jasper townsite study area, Jasper National Park.

Cultural Period	Length of record	Number of fires	Mean Interval between fire years (range)	Number of Major Fires	Mean Interval between Major Fire* years (range)	Area covered by Major Fires* (%)	Forest burned per year (%)
Total Period (1665 - 1975)	310	72	4.4 (1-36)	24	8.4 (1-2)	300.5	0.98
Park Period (1913-1975)	62	26	2.4 (1-6)	--	--	--	0.004
Railroad Period (1909-1912)	3	1	--	--	--	--	--
Settlement Period (1892-1910)	18	15	1.1 (1-2)	3	1.3 (1-2)	15.5	0.99
Presettlement Period (1830-1892)	62	16	3.7 (1-9)	13	4.6 (1-11)	185.8	3.00
Fur Trade Period (1800-1830)	30	4	4.7 (1-10)	1	27	8.2	0.28
Pre-European Period (1665-1800)	135	9	16.5 (9-36)	6	16.6 (10-22)	91.1	0.69

*Fires burning more than 500 ha are termed "Major Fires" in this study.

area decreased causing MFRI to increase to an average of one fire every 4.4 yrs. There have been no major fires since 1908 and only 0.004% of the area burned per year.

Unlike other major corridors through the Rocky Mountains, there was no decrease in MFRI in the Athabasca and Miette River valleys during the brief Railroad Period (1909-1912). There is, in fact, a small increase in number of fire scars for this period, but only a negligible area was burned (Table 2). The only fire year recorded for the Railroad Period was 1910. Locations are in close proximity to the railroad and therefore they may have been caused by man (Figure 12). The increase in MFRI for this period has been attributed to wet weather during the fire seasons, better patrols on the railroad right-of-ways, and legislation requiring spark arrestors on locomotives (MacMillan 1909, MacMillan and Gutches 1910).

The Settlement Period (1892-1910) experienced the shortest MFRI with a fire occurring every 1.3 yrs. However, the total area burned per year was only 0.99% for the Settlement Period whereas 3.0% burned per year in the previous period. Most fires during the Settlement Period were small. However, three major fires occurred covering a total of 15.5% of the study area.

Fires of the Presettlement Period (*ca.* 1830-1892) account for most of the *ca.* 300% of the study area burned during the period of record 1665-1975 (Table 9). Three percent of the area burned per year, and 13 of the 16 fires occurring in this period were of major extent.

Contrary to conventional expectation, the Fur Trade Period (*ca.* 1800-*ca.* 1830) showed no increase in fire frequency. Only four fires are recorded, of which one major fire is responsible for most of

the area burned during this period.

Despite the long MFRI of 16.5 yrs for the Pre-European Period (1665-*ca.* 1800) and the loss of fire-scar evidence with time, the total area burned per year was more than that in the Fur Trade Period and almost equal to that in the Settlement Period. This fluctuation in the past suggests that human activity in the area is possibly not the only factor having an effect on the periodicity and areal extent of past forest fires.

Byrne (1968), Day (1972) and MacKenzie (1973) have shown that there was a general increase in the frequency and extent of fire in the late nineteenth and early twentieth centuries on Alberta's East Slopes. Although their methods differ, the trends in forest burned per year are the same as those for Jasper (Table 10). Byrne and Day concluded that this increase was the result of increased activities by the white man during this time period. However, MacKenzie found that Waterton Park was virtually ignored by the white man during the nineteenth century. He therefore did not believe that European man was an important cause of forest fires during this period. The erratic but continual presence of man in the Jasper area suggests that MacKenzie's conclusions are probably true for my study area as well.

Similar estimates of forest burned per year have been obtained by separate workers from different places in the Canadian Rockies, indicating that the frequency and areal extent of forest fires has been similar throughout the region. However, the areas investigated have not experienced closely similar human-use patterns. Thus it would seem that there is some other factor overriding man as an ignition source that governed the frequency and areal extent of past fires.

TABLE 10. Minimal forest area burned per year for the Crow's Nest Forest, Waterton Lakes National Park, and the Jasper townsite study area. Although no data are available, Byrne (1968) has shown these same trends for Banff National Park using historical information.

Area	Period	Number of years	Forest of fire origin (%)	Minimum Forest Area burned per year (%)
Crow's Nest Forest (from Day 1972)	1830 - 1870	40	12.8	0.32
	1871 - 1890	20	23.3	1.16
	1891 - 1910	20	36.1	1.80
	1911 - 1930	20	4.4	0.22
Waterton Lakes National Park (from MacKenzie 1973)	Before 1800	?	12	?
	1800 - 1830	30	8	0.27
	1831 - 1850	20	2	0.10
	1851 - 1870	20	9	0.45
	1871 - 1890	20	34	1.70
	1891 - 1910	20	28	1.40
	1911 - 1972	61	7	0.12
Jasper Townsite Study Area (this study)	1665 - 1800	135	91.1	0.69
	1800 - 1830	30	8.2	0.28
	1831 - 1892	62	185.8	3.00
	1892 - 1910	18	15.5	0.99
	1909 - 1912	3	--	--
	1913 - 1975	62	--	0.004

Byrne (1968) qualified the role of man as an ignition source by stating that changing environmental conditions were also important. He showed that warmer and drier conditions developed in the Banff area during the second half of the nineteenth century, and that this climatic change resulted in environmental conditions that were more suitable for forest fires.

The area burned per year in the Jasper study area fluctuated erratically and was not consistent with human-use patterns. This lack of correlation, plus the fact that my data show a larger area burned per year before the arrival of European man, suggest that climate was the principal factor controlling the frequency and extent of past fires.

Fire History and Past Climate

It is well known that certain combinations of climatic and weather conditions increase the probability of fire. Low humidity and low precipitation coupled with high temperatures and solar radiation lower the organic matter moisture content and therefore increase fire potential (Haines and Sando 1969). Specific causal factors leading up to major fires are not known, but a combination of weather and climatic factors may induce drought which generally promotes and sustains such fires. Once an ignition source is supplied under dry conditions, wind becomes the most critical factor leading to fire spread.

Haines and Sando (1969) investigated weather conditions preceding seven major historical fires in the north central United States. The most striking meteorological factor was decreased precipitation over a 3-8 month period. Frequency of precipitation,

amount of solar radiation, and abnormally hot weather varied from fire to fire and provided little additional insight. Heinselman (1973) analyzed weather data before a number of major fire years back to 1863 and found that they were characterized by summer droughts, or droughts that extended from the summer into fall. Comparison of the fire history of the Bitterroot Mountains with National Weather Service records for 1870-1920 revealed that fires were strongly correlated with drier-than-average summers (Arno 1976). Armstrong and Vines (1973) analyzed long-term rainfall records for southern Canada, and found that incidence of forest fires correlated well with approximate periodic drought patterns. Although they had few data before 1920, their records indicate that well known "historic fires" also fit the drought correlation. Therefore, the most consistent meteorological indicator of past forest fires has been precipitation.

No precipitation records exist for the Jasper study area before 1926. Limited data are available for Entrance outside the Front Ranges (53°22'N 117°41'W) for 1918-1947. However, this period also falls outside the range of major fires that occurred prior to the implementation of fire control in 1913. Therefore, reliance was placed on regional climatic trends as indicators of major drought years or periods, which in turn might correspond to fire years.

One source of past climatic information is the tree-ring record. Dendrochronology is the science of dating annual growth rings in woody plants, and dendroclimatology uses the information to interpret various aspects of past and present climates (Fritts 1971). Precipitation and temperature are the two major factors controlling the water and heat balance in a tree which in turn affects photosynthesis,

respiration and growth. In dry regions seasonal variations in both precipitation and temperature are reflected in the ring width of conifers (Stockton and Fritts 1971).

Several attempts to correlate severe fire years with precipitation cycles determined from tree ring studies have met with marked success (Marshall 1927, Byrne 1968). Fritts (pers. comm. 1 Feb. 1977) believes that dendroclimatology can be a very important tool for fire ecology studies. An analysis of cores from the Boundary Waters Canoe Area, Minnesota, indicates that low-growth years correspond to the fire years established by Heinselman (1973).

Schulman (1956) and Stockton and Fritts (1971) have shown that the warm and dry climate of the Athabasca River valley is very well suited for such studies. Measured ring widths are transformed to indices by fitting a straight line or modified exponential curve to the measured ring-width series. Indices are formed by dividing the respective ring widths by the corresponding value of the growth function and can be thought of as a percent of the *expected* growth per year. The transformation is necessary in order to convert the non-stationary ring-width series to one that is stationary (one whose mean and variance are not functions of time). This method is standard procedure at the Tree-Ring Laboratory in Tucson, Arizona, and is described in detail in Stokes and Smiley (1968) and Fritts (1971). Schulman's graphs show a marked correlation between ring width and annual rainfall records for both Entrance and Banff (Figure 51). The correlation coefficient for growth to rainfall was +0.6-0.8 (Schulman 1956). If we accept Schulman's correlations, then it seems appropriate to use negative departures from mean growth rates of low-elevation trees

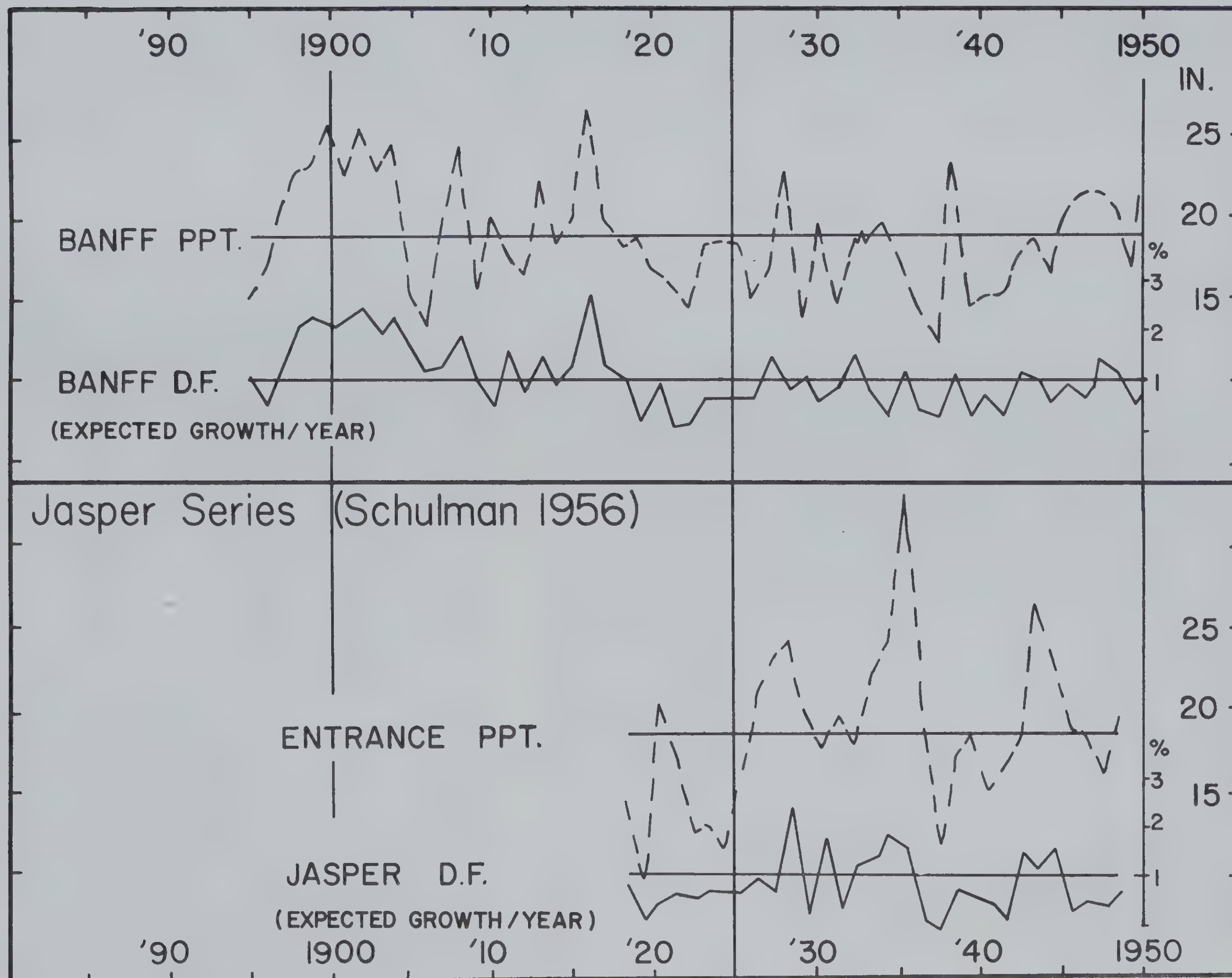


Figure 51. Precipitation record and dendrochronology of Douglas-fir(D.F.) for Banff and Jasper (see text for methods).

on well-drained sites as indicators of dry climatic trends before 1918.

Precipitation departures for the period 1700-1913 were determined from Figure 52 (Table 11). The end dates are somewhat arbitrary because they were read off the plotted curves where they significantly crossed the mean line. For significance, the "swing of the curve" across the mean line (growth expectancy = 1.0) had to last for at least two years and reach as much as 10% below the mean. Minima of one year were noted only when very pronounced (>10%).

Half of the time period 1700-1913 experienced below-mean precipitation. When all fires between 1700-1913 were plotted against these below-mean precipitation periods, 75.6% of the fires and 91.9% of the total area burned was accounted for (Table 12). The 1758, 1847 and 1889 fires occurred during these pronounced droughts and accounted for 60.5% of the total area burned during the period of record. Only 8.1% of the area was covered by fires during above-mean precipitation periods.

A comparison of different studies in Minnesota, Montana and Alberta shows many fire years in common (Table 13). The years 1714, 1758, 1807, 1834, 1846, 1847, 1858, 1863, 1883, 1884, 1889, 1904, 1905 and 1908 appear to have been major fire years in the northern Rocky Mountains. On a subcontinental basis, the four areas have fire years 1807, 1863, 1884 and 1904 in common. It is suggested that these similarities are related to major atmospheric circulation patterns associated with subcontinental droughts. However, more detailed comparisons of fire severity and extent in these years, and a more thorough investigation of past climate, are necessary before valid conclusions can be made.

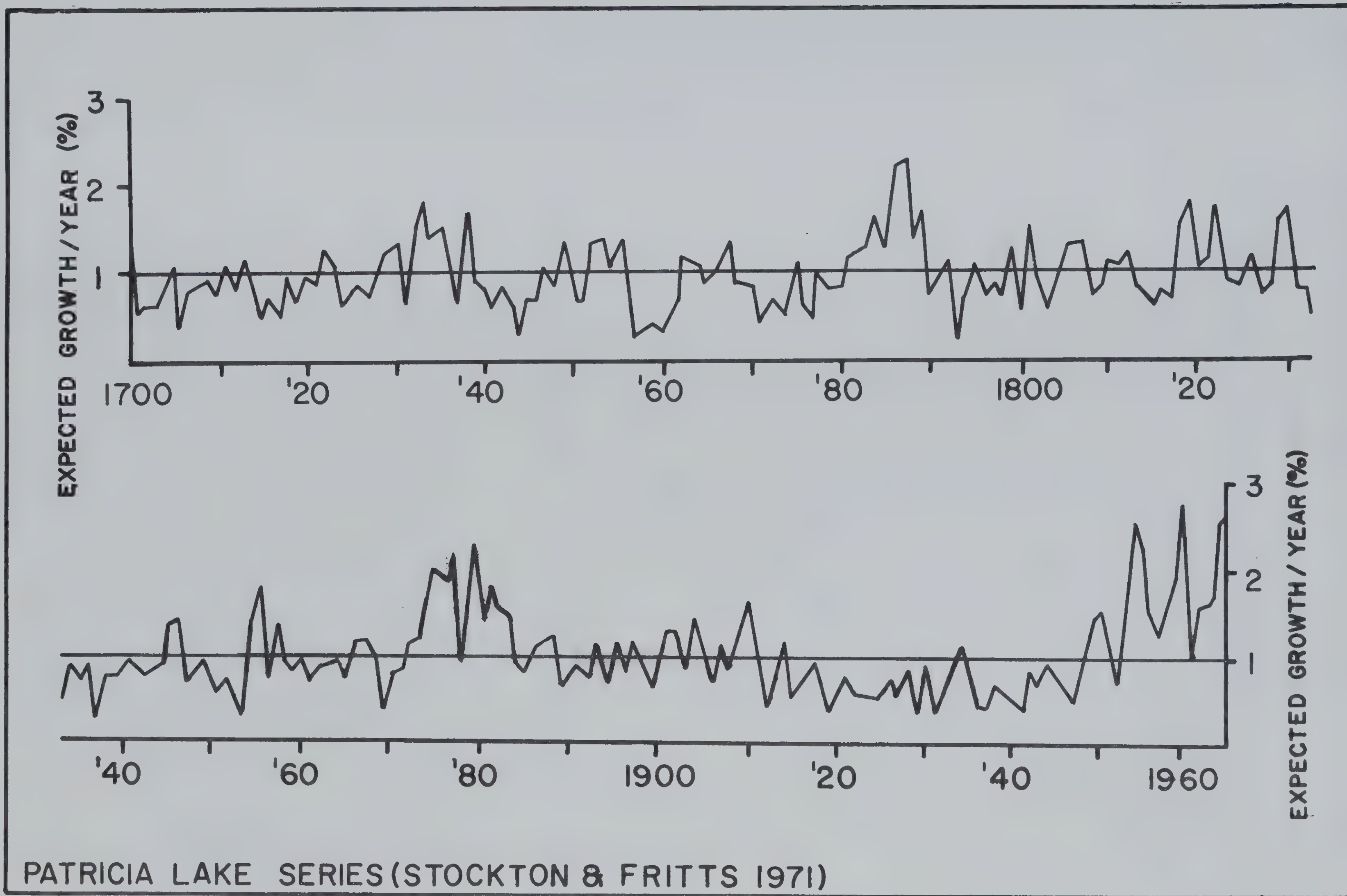


Figure 52. Dendrochronology for the Jasper townsite study area as determined from Douglas-fir, 1700-1965 (see text for methods).

TABLE 11. Years of below-mean precipitation trends for the Jasper study area, 1700-1913, as determined from the Patricia Lake dendroclimatological series of Stockton and Fritts (1971).

1712 - 1722	1813 - 1818
1724 - 1728	1823 - 1828
1731	1831 - 1844
1737	1846 - 1853
1739 - 1748	1858 - 1866
1750 - 1752	1868 - 1870
1756 - 1762	1883 - 1884
1768 - 1781	1889 - 1893
1790 - 1797	1898 - 1901
1801 - 1804	1907
1808 - 1810	1908

TABLE 12. Percent of fires occurring during below-mean precipitation periods, 1700-1913, in the Jasper townsite study area. These periods were derived from dendroclimatological studies of Stockton and Fritts (1971).

Data base	Number of fires	Number of fires in "dry" period	Percent fires in dry period	Percent of total area burned	Mean fire return interval (range)
All fires 1700 - 1913	36	28	75.6	91.9	3.1 (1-21)
Fires burning ≥5 km^2* (>1.2% of area)	24	18	75.0	89.2	8.4 (1-27)
Fires burning ≥10 km^2 (>2.4% of area)	17	13	76.5	88.4	11.4 (1-27)
Fires burning ≥25 km^2 (>6% of area)	10	8	80.0	81.2	19.9 (10-39)
Fires burning ≥50 km^2 (>12% of area)	6	6	100.0	76.0	32.4 (10-79)
Fires burning ≥100 km^2 (>24% of area)	3	3	100.0	60.5	65.5 (42-89)

*A "major fire" for this study.

TABLE 13. Correlations between major fire years[1] of the Jasper townsite study area and other historical and tree-ring fire studies in North America.

JASPER (This study)	BANFF (Byrne 1968)[2]	MONTANA (Arno 1976)	MONTANA (Gabriel 1976)	MINNESOTA (Heinselman 1973)
1908		1908		
1906				
1905		1905		
1904		1904	1904	1904
1889	1889	1889	1889	
1888				1888
1884	1884			1884
1883	1883	1883		1883
1880				1880
1869	1869			
1861				
1858		1858	1858	
1847	1847	1847	1847	
1846	1846	1846	1846	1846
1837				
1834		1834	1834	
1807		1807	1807	1807
1797				1797
1780			1780	
1758		1758		1758
1737				
1727				1727
1714		1714		
1678?				
1665?		1668?		

[1]Major fire covered 5 km^2.
[2]As determined from historical records.

The dendroclimatic record for Jasper has numerous short and long-term below-mean precipitation periods, and many fire years correspond to them. The probability of fire certainly was higher during such "favorable" weather conditions. I therefore conclude that climate has been *the* major environmental factor controlling the frequency and extent of past forest fires.

Byrne (1968) stated that the frequency and extent of fire in Banff National Park increased during the nineteenth century as a result of a combination of an increasingly favorable environment for fire and the arrival of the white man. A similar trend of increasing fire frequency and extent occurred in Jasper. The correlation between past climate and fire history and the erratic human-use patterns associated with the Athabasca River valley suggest that the white man alone should not be blamed for the extensive forest fires of the nineteenth century, since he arrived in the area at a time when conditions were more favorable for such fires.

Severity of Past Fires

The ecological effects and behavior of past fires in the study area depended on many interacting factors. The most important were weather and climate before and during the fire, vegetation types, amount and pattern of accumulated organic matter, and features of the physical landscape (Heinselman 1973). Survival and regeneration of many herbs, shrubs and trees were affected by the extent of crowning and direct overstory kill, and the amount of organic matter consumed. Severity of past fires is therefore a key factor for developing an understanding of the importance of fire to the biotic communities of the

study area.

Most investigators have not recognized the importance of defining and characterizing the extent and severity of past fires. Wellner (1970) stated that most forested communities of the northern Rocky Mountains were characterized by severe, high intensity fires, except where Douglas-fir and ponderosa pine (*Pinus ponderosa*) were the dominant vegetation types. My initial inability to critically examine such statements led to confusing questions about the fire history, the main one being: Why are there so many fire-scarred trees scattered throughout the study area and yet so very few distinct fire margins?

The extent and intensity of past forest fires in the Jasper study area have been alluded to in previous considerations of the stand origin and fire year maps. Several lines of evidence are interpreted below to assess the severity of these fires.

Evidence for the widespread nature of past burns was indicated by abundant fire sign such as scarred trees, charred stumps, standing and fallen fire-killed snags, charcoal in the soil and old fire margins. One or more of these signs was found in 420 of 520 stand origin plots analyzed the first summer.

The widespread occurrence of similar-aged scars indicated frequent and extensive fires. Trees with multiple fire scars were not restricted to natural fire breaks but were scattered throughout the area. This suggested a long history of low to medium intensity surface fires which consumed undergrowth and litter accumulation but did not eliminate all overstory elements.

The frequent incidence of past fires suggested that they were generally not of high intensity because of the limited time for organic

matter accumulation (Table 2). The stand origin map depicts a very complex mosaic of age structures which in turn indicates frequent, non-holocaustic fires that left substantial remnants of the living forest.

Major fires of medium to high intensity did occur (1758, 1847, 1889) and destroyed large areas of the previous forests. However, even these fires resulted in a mosaic of heterogeneous to even-aged stands, rather than vast areas of even age.

In even-aged stands, the last fire was intense enough to destroy all the above-ground elements within the area (Figure 53). Although not infrequent in the valley bottom, the larger even-aged forests were more common on the upper slopes of the study area (Figure 12).

A common pattern was that of two age classes dating from separate fires (Figure 54). This suggests a fire of low to medium intensity that was hot enough to remove parts of the former stand, scar occasional remnants and provide for the regeneration of a new age class. Such age structures are most widespread in the valley bottoms and become less frequent with increasing elevation (Figure 12, Results, page 109).

The most common stand age assemblage in the study area was a complex, fine-scale mixture of several age classes. In this mosaic, post-fire individuals dating from separate fires were found within short distances of each other (Figure 55). These complex, fire-produced age structures are most commonly found in rugged terrain of the Miette River valley west of Jasper townsite and below the Pallisade (Figure 12). They resulted from frequent, low- to medium-intensity fires that responded to complex physiographic moisture gradients.

Figure 53. Mr. Doug Currie standing in an even-aged stand of lodgepole pine. Stand dates from the fire of 1889 (photo 45-3, 15 August 1974).

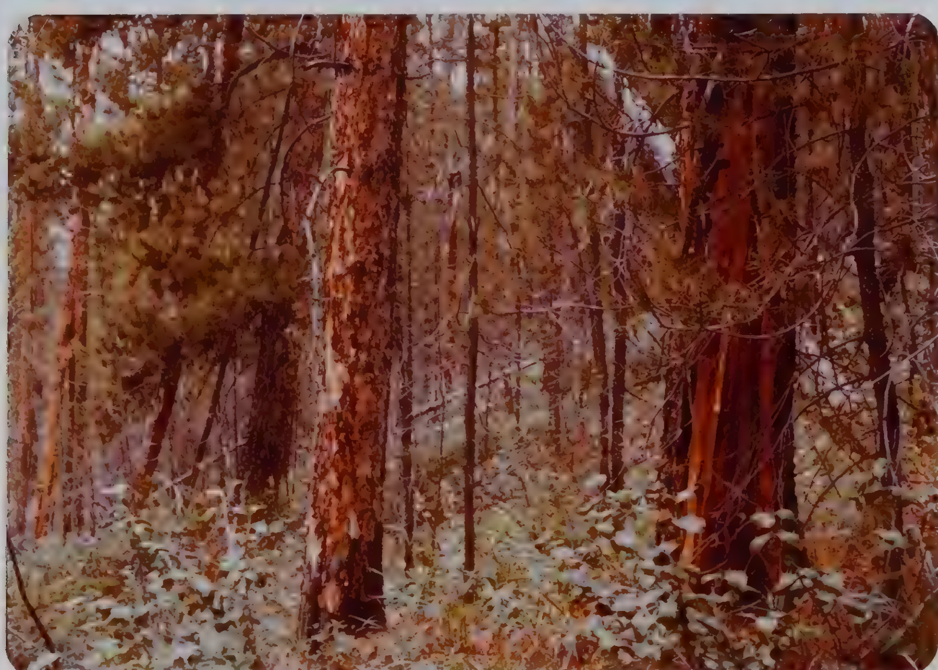


Figure 54. Two-aged stand of lodgepole pine. Smaller trees date from the 1889 fire. Larger trees originated after the 1758 fire and were scarred by the fire of 1889 (photo 19-3, 17 July 1974).

Figure 55. Fine-scale mixture of age classes. Stand in the foreground dates from the 1889 fire. Stand in the background dates from the 1905 fire. The stand of 1889 origin is repeated 50 m behind that of 1905 origin (photo 29-7, 29 July 1974).

Some stands contained scar dates but no regeneration originating from that fire year. This pattern was most prevalent in Douglas-fir, but was also very common in many remnant lodgepole pine forests at lower elevations (Figures 56 and 57). Since lodgepole pine is a highly fire-susceptible tree species, such fires must have been of low intensity and confined to the ground layer. To scar fire-resistant Douglas-fir, they must have been of moderate intensity, but not hot enough to enter the crown. In both cases, fires were not intense enough to remove the forest overstory and thus stimulate regeneration of shade-intolerant conifers.

Fire intensity was correlated with moisture regime and organic matter accumulation on a slope angle, slope aspect and elevation basis. Frequent low intensity fires characterized the xeric valley bottoms and open south- and west-facing slopes at lower elevations (Figure 58). In grassland-savanna, these fires maintained several-aged lodgepole pine and Douglas-fir by periodically removing the low accumulation of litter. This further insured that recurring fires would be of low intensity.

Lodgepole pine forests surrounding the open areas of the valley bottoms exhibited a more complex age structure. Even-aged stands occurred locally where organic matter accumulation was high. Some of these stands are interspersed with relics from past fires (Figure 54). Where the moisture regime was more mesic, more organic matter accumulated (*e.g.*, north- and east-facing slopes), and fires burned more intensely when drought conditions prevailed (Figure 59).

This relationship between moisture regime, organic matter and fire intensity is directly related to elevation. Since conditions

Figure 56. Wabasso Creek Douglas-fir forest (October 1975).

Figure 57. Lodgepole pine stand harboring fire scars from 1758, but no regeneration originating from that fire year. This is evidence for creeping surface fires in lodgepole pine forests (photo 45-1, 15 August 1974).

Figure 58. Wabasso Creek grassland-savanna. Periodic fires maintained open-grown, variably-aged lodgepole pine and Douglas-fir (October 1975).

Figure 59. Organic matter accumulation on north-facing slope near Riley Lake 2 km west of Jasper townsite (photo 29-3, 29 July 1974).

at higher elevations are mesic and cooler for longer periods of time, organic matter accumulations tend to become greater between consecutive fires. When dry conditions do prevail, the large organic matter accumulations insure a high intensity fire. Even-aged forests are therefore more extensive at middle to high elevations in the study area. Vast areas of two or more age classes reflect the severity of fire on south-southwesterly slopes such as those on the Colin and Maligne Ranges (Figure 12). Lower organic matter accumulations on these drier slopes carried subsequent low to medium intensity fire that left many remnants. Conversely, north-facing slopes were more intensely burned, but fires occurred on them less often. Extensive areas on north- and east-facing slopes of Marmot and Signal Mountains are even-aged and date only from the last major fire.

Based on these observations, it is concluded that pre-1913 fires in the study area were mostly low to medium intensity. Occasional medium to high intensity fires occurred, but even these burned sporadically leaving many relic stands and individual trees across the area.

Heinselman (1973) recognized that fires had left a mosaic of age structures across the Boundary Waters Canoe Area, Minnesota, and that many of these were of multiple age traceable to separate fires. Such behavioral evidence has also been noted for the boreal forest (Rowe and Scotter 1973) and the Rocky Mountains (Habeck and Mutch 1973, Arno 1976). Surface fires in Douglas-fir savanna-woodland have been studied by Houston (1973). Other investigators have shown that creeping surface fires are not uncommon in lodgepole pine forests (Horton 1956, Loope and Gruell 1973, Gabriel 1976).

Arno (1976) specifically examined the problem of extent and severity of past forest fires in the Bitterroot Mountains of Montana. He showed that frequency and intensity varied significantly between vegetation types and also between different portions of the study area. Further, although high-intensity, stand-destroying fires were detected in certain habitat types, most historical fires were of low intensity and left substantial remnants of the previous forest. Thus, the pattern of fire severity exhibited by the forests of the Jasper townsite study area is comparable to observations in other areas and is closely similar to that of the Bitterroot Mountains in Montana.

Interrelations of Plant Succession, Organic Matter Accumulation and Fire

There is a gradual increment of biomass as forest ecosystems reestablish following a major disturbance such as fire. Many workers believe that (1) factors associated with plant succession increase the probability that older stands will burn, and (2) fire plays a critical role as a "decomposer" of organic matter that accumulates with time (Habeck and Mutch 1973, Heinselman 1973, Wright and Heinselman 1973).

This thesis has shown that the frequency and severity of past forest fires in the Jasper study area were related to complex patterns of organic matter accumulation. It is therefore useful to relate the buildup of organic material to processes of plant succession to assess changing forest flammability with time.

Two major plant/fuel successional sequences may be recognized in the study area: one in high-elevational forests and one in low-elevational forests. Both are characterized by distinct fire regimes that correspond to organic matter accumulation. The following

generalized sequence might be observed as these forests develop.

Low-Elevational Forests. Fires of low to medium intensity are characteristic of low-elevational forests. The understory is partially consumed and remnant individuals or stands are left intact depending on local moisture regimes and organic matter accumulations. All foliage and twigs are partially or wholly consumed by the first fire, but charred trunks with branches and twigs are left standing. Relatively high concentrations of potential fuel are present after a fire, but susceptibility to a second fire is low. Organic matter accumulations on the landscape are broken up leaving widely-spaced, uncured, fire-killed snags having low surface-to-volume ratios. The vertical and hortizontal dispersion of unconsumed organic material is not conducive to fire spread.

With time, foliage, twigs and branches fall off, smaller roots decompose and wind slowly levels all trunks to the ground, creating a "fire-fall". In the meantime, young pine, spruce and Douglas-fir have become established on open and exposed mineral soil. The combination of fallen fire-killed snags and dense young regeneration makes the stand almost impenetrable and increases both the amount and continuity of fuel for a potential fire. Should a second fire occur at this stage during some dry period, all available organic material would potentially be consumed. Without fire, secondary growth of the forest will attain full size and fire-fall trees gradually decompose and disappear.

Pine regeneration ceases within 40 yrs after the initiating fire (Horton 1956, Day 1972, results this study). Natural thinning progresses as the dense young stand matures. A higher fire potential

would be expected at the beginning of this stage if natural thinning started before the fire-fall had completely decomposed. Fire potential declines as thinning proceeds and the thinned and fire-killed snags decompose.

A second minimal fire potential is reached during mid-life of the stand at about 50-100 yrs. Such a stand is composed of widely-spaced trees that have matured since natural thinning. Organic matter accumulation is restricted to sparse woody and herbaceous lichen-moss, herb, and shrub strata, and the highly flammable needle litter. Most of the fire-fall and natural thinning has been decomposed or is covered by the lower vegetation strata and a duff layer. Stands are open and characterized by a distinct lack of natural thinning and fire-killed snags. It is estimated that the fire-fall becomes unimportant to fire spread and intensity in 40-60 yrs, but large trunks may persist longer. This rapid decomposition is attributed to a "dry-rot" process dependent on the warm, dry climate of the valley bottom. Moisture swells the fallen individuals and the warm, dry air causes rapid drying. This cycling between wetting up and rapidly drying out leads to disintegration of the thinning and fire-fall which settle and become part of the duff layer that is slowly covered by the understory strata and needle litter. Low productivity in the warm, dry environment and grazing by ungulates also lowers total organic matter accumulation in the valley bottoms. Frequent, recurring, low-intensity surface fires further reduce and maintain these low accumulations. Thus, micro- and macro-climatic factors control organic matter buildup which is responsible for the frequency and intensity of fires at lower elevations in the study area.

Throughout the early growth of the pine population, spruce and Douglas-fir slowly become established from seeds released seasonally from residual trees. In many instances, the latter species come in with pine after the fire, but pine is numerically superior, grows more rapidly and forms the upper canopy. Dry, open conditions and frequent, low-intensity surface fires encourage pine and kill the then highly flammable climax species.

As these lower elevational stands mature, pine may be replaced by spruce on mesic sites and Douglas-fir on more open xeric sites. The young spruce and Douglas-fir are "fuel ladders" capable of carrying fire into the overstory because of their highly flammable foliage (Flint 1925). The vigor of these trees increases as that of pine declines with stand maturation. Stands open up as pine density declines, further drying the understory. Litter accumulation is partially removed by decomposition, but total organic matter slowly accumulates as new regeneration of pine, spruce and Douglas-fir occupy the openings. Since lodgepole pine is not completely serotinous in the study area, it sheds seeds which can reestablish on disturbed sites. Thus pine is constantly present, but of varying vitality in the life of low-elevational forests.

High-Elevational Forests. These forests are characterized by less frequent but higher intensity fires. The organic matter accumulation sequence is similar, but slower, to that of lower elevational forests. Organic material that is potentially available to burn falls virtually to zero after fire, and accumulates with time as regeneration develops and a fire-fall is created. Higher fuel accumulations result

20-50 yrs after fire because of lower temperatures and slower decomposition at higher elevations. The mid-life of decreased flammability is not as pronounced or as long as that of valley bottom forests because organic matter accumulations are not decomposed as fast. Vigor of spruce and subalpine fir increase as pine declines. Spruce and fir gain dominance during the mid-life of pine extending from 70-240 yrs (Horton 1956, Day 1972). Fire susceptibility of these stands increases as the crowns of these flammable species enter the pine canopy.

As the forest matures, disease-caused mortality of trees increases, which promotes a higher susceptibility to fire. Openings in the canopy are created as pine declines in the stand and the dead individuals fall. Such openings increase insolation and air movement thereby drying the accumulated organic material and increasing the fire hazard. For stands which escape fire for more than 250 yrs (Figure 49), new regeneration and the windthrow of tops, branches and boles of pine accumulate with age (Day 1972). Under such conditions, it would only be a matter of time before a dry lightning strike would reinitiate the succession under the proper climatic conditions.

In summary, it is important to note that forests of the study area vary in flammability through time and space, *i.e.*, plant successional stage, slope, aspect and elevational positions. The interrelationships between fire-related components and elevation are portrayed in Figure 60. The more frequent fires in the warm, dry lower-elevational sites were less intense because organic matter decomposition was faster. Likewise, fires that burned into upper elevational forests were less frequent but more intense because of cooler, wetter conditions,

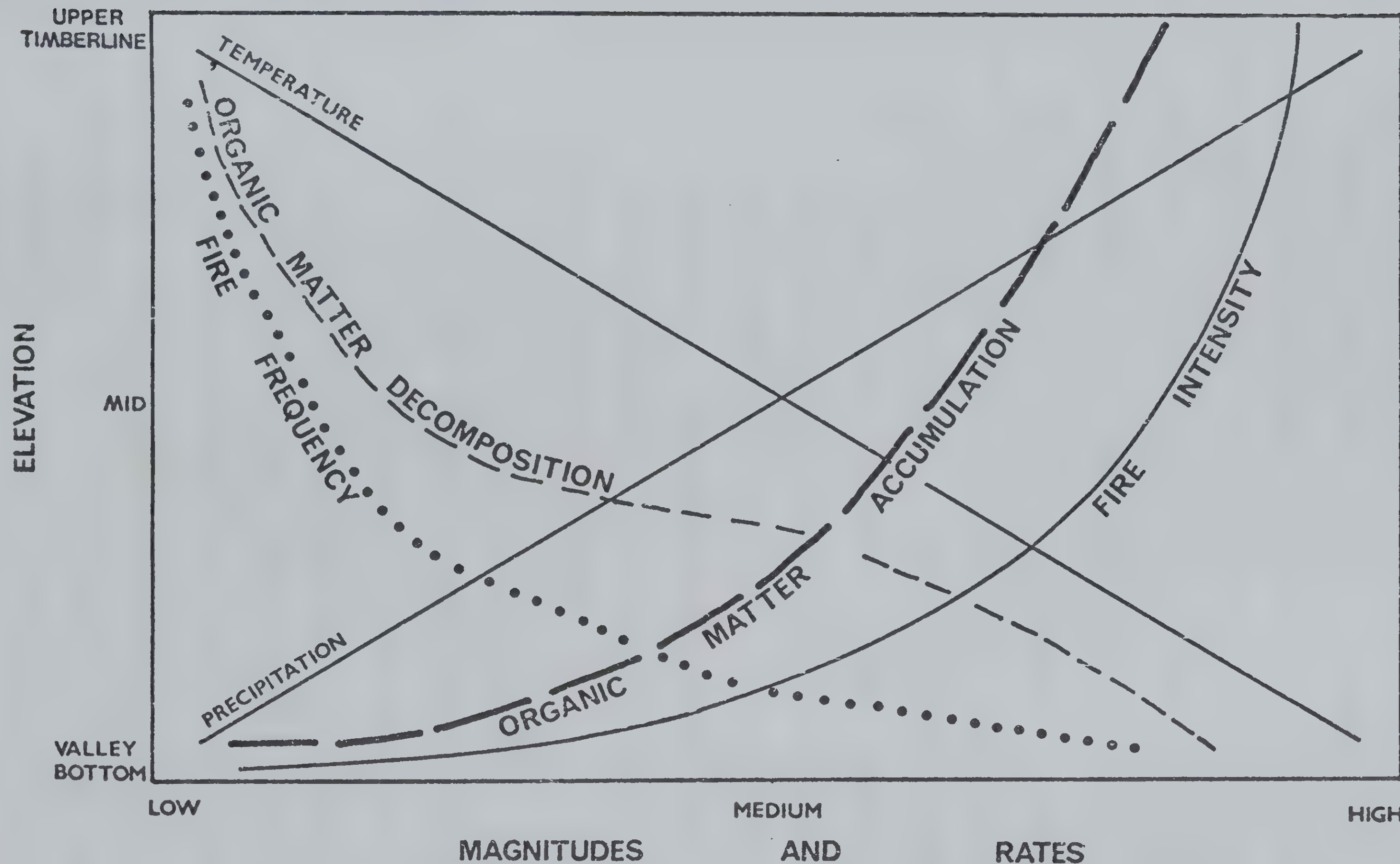


Figure 60. Diagramatic representation of interrelations among fire-related components and elevation in the Jasper townsite study area. (Temperature and precipitation are approximated and not based on results from this study)

slower decomposition rates and a more highly flammable fuel accumulation.

Organic matter accumulation is on the decline from post-fire maximum fuel loading on a significant portion of the study area, *e.g.*, stands originating after 1904 (Figures 12, 14-18). To this extent, the fire hazard is declining. The mid-life organic matter accumulation minimum is long-lived at lower elevations because of rapid decomposition rates. Thus, the flammability of these forests is lower for a longer period of time than high-elevation forests. Flammability begins to increase when spruce and Douglas-fir establish fuel ladders into the crown of the older, less vigorous pine. The mid-life fuel minimum is shorter at higher elevations because removal of organic material is not as fast as that in lower elevational forests. These observations are schematically compared in Figure 61. The logical conclusion is that organic matter accumulation is increasing on most of the area where burning was more than approximately 80 yrs ago at lower elevations and more than 70 yrs ago or less at higher elevations.

It is recognized that the two sequences presented above are oversimplified and many factors can modify organic matter accumulation curves on any given site. More information is needed on organic increment with time under different site conditions. The stand origin map provides a time-scale reference for further investigations.

Heinselman (1973) hypothesized that the pattern of occurrence and the severity of past forest fires was regulated by fuel factors related to vegetation type, stand age and successional stage interacting with climatic oscillations. He felt that lightning and man were both ignition sources, but since the probability of lightning-caused ignitions approaches certainty with time, it alone would have been an

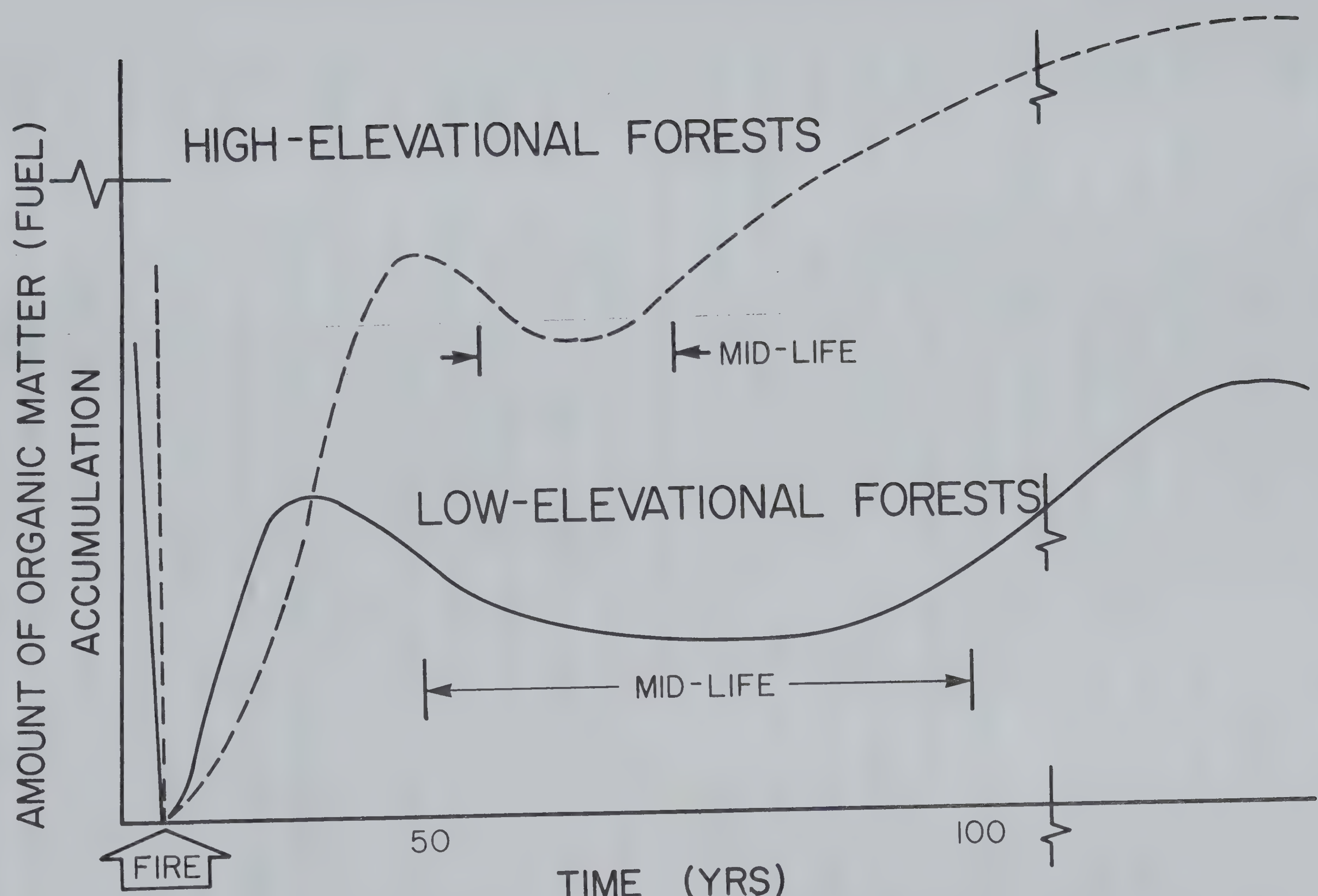


Figure 61. Schematic representation of flammable organic matter accumulation through time (fuel succession) for high- and low- elevational forests in the Jasper townsite study area.

adequate source of ignition to guarantee that all flammable stands would eventually burn.

The pattern of past forest fires in the Jasper townsite study area supports Heinselman's hypothesis. The estimated size of past fires form a series of irregular exponential curves (Figure 8). These fluctuations are attributed to oscillations in past climate and in the accumulation of organic material with time.

Integration of the fire history data, stand successional sequences and Heinselman's hypothesis leads to the conclusion that forests of the Jasper townsite study area will eventually burn again. As well, the longer they are without fire, the more organic material will accumulate and the more severe will be the fire given favorable weather conditions. Once such a fire has occurred, the organic matter is reduced and stand maturation processes begin again.

In the past, the cumulative impact of previous fires was a heterogeneous pattern of age structures and organic matter on the landscape. This pattern regulated the frequency, intensity and areal extent of subsequent fires. Since eventually even the larger fires extended into areas of lower flammability, the burns themselves maintained the mosaic.

The present pattern is by no means as heterogeneous and dramatic as it must have been in the past, because younger forests have matured since the last big fires. The ecological role of fire has been disrupted due to an active suppression compaign since the park was established in 1907. As a result, organic matter is accumulating faster than it is being consumed as plant successional sequences proceed through time. Therefore, I predict that given the proper

weather conditions and an ignition source, the Athabasca, Miette and Maligne River valleys around Jasper townsite will experience a fire or series of fires that may well be larger and more catastrophic than any recorded during the period of record, 1665 to 1913.

Climate as a Factor in Fire History Investigations

The severity of past forest fires in the Jasper townsite study area has been shown to be related to complex moisture and organic matter gradients. Regional weather and climate were the overriding factors determining the frequency and areal extent of fires. Weather and climate determined not only the rate of organic matter accumulation, and therefore the amount of fuel, but also whether or not the fuel at a particular place and time would burn once ignited.

Most fire ecologists and foresters have used mean fire return intervals (MFRI) to characterize the frequency of fire in the vegetation type or ecosystem investigated (Frissell 1973, Heinselman 1973, Houston 1973, Loope and Gruell 1973, Cwynar 1975, Arno 1976, McBride and Laven 1976). Such descriptions have been used for further interpretive or management purposes, as if these mean values were static and representative of that vegetation type or ecosystem through time. Although many investigators have shown marked correlations between drier-than-average precipitation periods and major fire years, few if any have considered the climatic variability for more than their period of record. Climate may vary on a short- and long-term basis between cool-moist and warm-dry periods. Individual fire years may be associated with either short-term or long-term climatic cycles, but a higher fire frequency must be associated with the long-term dry periods.

Whether or not the fire history investigation period overlaps or falls within long-term climatic oscillations is a problem that has not been seriously considered by fire ecologists or land managers.

Long-term climatic trends in the study area have oscillated between cool-moist and warm-dry conditions. Of significance to this study is the fact that the climate between 1700 and 1950 was relatively warm and dry with the exception of short-term cool-moist periods in the 1730's, 1780's and 1870's; cooler and moister long-term climates prevailed before and after this period (Byrne 1968). Figure 52 shows the dramatic shift from a warm-dry to a cool-wet climate after 1950. This change of climate before and after 1950 has not been confined to the Canadian Rockies, but is recorded on a continental basis. Detailed reviews on this subject can be found in Byrne (1968), Bray (1971) and Porter (1976).

The existence of a readily-combustible community depends largely upon past climate and present weather. Once a community type is established in an area it changes very slowly in response to long-term climatic changes (Wright 1976). Short-term fluctuations on the order of a few decades will generally not be reflected in radical changes in community physiognomy or species composition, or in rates and amounts of biomass accumulation. However, long-term changes are likely to have a measurable and important effect on all of these community attributes, affecting the quantity and flammability of the available organic material, and consequently the frequency, intensity and areal extent of fires.

These long-term fluctuations raise many questions concerning fire as a ecological factor. Byrne (1968) suggested that the

widespread fires in the Banff area following the arrival of the white man coincided with warmer, drier climate, and thus may have led many authors to over-estimate the importance of fire in vegetation change under natural conditions. Based on the extensive fire ecology literature available today, I do not believe that the importance of fire has been overstated. However, not enough attention has been paid to the effects of long-term climatic fluctuations on the frequency, intensity and extent of past fires.

Fire has been shown to be an integral part of the Jasper environment, but its role and importance have changed with changing climate. Given a long period of extended drought, one would expect more frequent low-intensity fires with occasional extensive high-intensity fires. Likewise, one would expect less frequent but high-intensity fires and fewer low-intensity fires during long periods of cool and moist conditions, since organic material would have built up between successive fires. Thus mean fire return intervals, extent and intensity of fires for a given vegetation type or ecosystem are not constant values but vary with major climatic changes.

I therefore postulate that the periodicity of fire for any given study area is valid only for the period of record investigated and extrapolation of such information to the present or further into the past must be undertaken with extreme caution. Although past climates have been shown to be cyclic in nature, the periodicity of warming and drying trends have varied greatly and therefore are essentially unpredictable. Mean fire return intervals determined for a period of a warmer, drier climate cannot be used to characterize periods of cooler, wetter climate.

Since regional climate and weather are the overriding factors governing regional fire history, Heinselman's hypothesis can be modified as follows: The frequency, extent and intensity of forest fires are governed by both short- and long-term climatic oscillations that regulate fuel factors related to vegetation type, stand age and successional stage. The probability that a forest will burn approaches certainty with time, given a proper combination of these factors and a dry lightning strike. But the periodicity at which they burn is governed by long-term cycles between warm-dry and cool-moist climatic conditions.

Implications and Management Recommendations

The major thesis of this study is that fire was an integral part of the coniferous forests in the Athabasca, Miette and Maligne River valleys around Jasper townsite, Jasper National Park. In the past, land managers have tended to regard fire as an undesirable disturbance rather than a natural factor in the environment (Mutch 1970). This is the situation in Jasper National Park today where a fire suppression policy has been in effect since 1907.

Relevant literature on integration of fire ecology and management planning can be found in Heinselman (1970, 1973, 1975), Mutch and Habeck (1975), USDA Forest Service (1975) and Arno (1976).

In a fire-dependent ecosystem, exclusion of fire disrupts natural processes. Heinselman (1975) listed the following probable ecological changes that would occur as the result of fire exclusion from the Jasper environment:

1. "Closing up of savanna-woodlands and grasslands,

2. "Aging of many forest stands beyond which might not otherwise have occurred,
3. "Unnatural progression of successional changes in some forests,
4. "Failure of stand regeneration due to lack of fire (there has been little regeneration since 1913),
5. "Changes in nutrient cycles, dry matter accumulation, energy flows,
6. "Changes in production of herbage and browse for wildlife (probably changes in species availability and nutrient value and perhaps reduced total production)."

This list of potential effects of fire exclusion is long and alarming, but the actual situation may not be as serious as it sounds (Heinselman 1975). First, most of the forests of the study area are not very old because most of them were regenerated by the fires of 1889, 1904, 1905, 1906, 1907 and 1908, just prior to active fire suppression. Second, organic matter accumulations in most of the lower elevational forests are not heavy due to low productivity, dry rot, overgrazing by ungulates, and occurrence of occasional surface fires. Third, the forests are relatively long-lived and succession is slow. Fire exclusion has therefore not had serious repercussions up to this point in time.

However, continuation of Parks Canada policy to prevent wildfires will almost certainly lead to the elimination of a strong environmental selection pressure that has been responsible for the evolution of the forest environment. These communities have characterized much of the region since the last ice age (Day 1972). If it is

desired to maintain these communities, then fire should be re-introduced. A well-planned program of fire prescription and control is needed to maintain the pattern of disturbance phases of the forest maturation sequence, so that a more natural mosaic will remain for future generations.

SUMMARY AND CONCLUSIONS

The objectives of this study were to document the fire history and investigate the interrelations of fire and the coniferous forests around Jasper townsite, Jasper National Park. Of primary concern was the interpretation of periodicity, location and areal extent of fires before 1907 when fire suppression was initiated. Cultural history and past climate were examined in relation to the fire regime. The severity of past fires was assessed to ascertain their impact on the coniferous forests.

Fire history techniques were used to establish a fire chronology for the 310 yr period 1665-1975. Seventy-two fires were recorded for the period using sections from fire-scarred lodgepole pine and Douglas-fir.

Maps were prepared for 45 fire years prior to 1910. Major fire years were 1908, 1906, 1905, 1904, 1889, 1888, 1884, 1883, 1880, 1869, 1863, 1861, 1858, 1847, 1846, 1837, 1834, 1807, 1797, 1780, 1758, 1737, 1727 and 1714. Most of the forested landscape today originated after the years 1889, 1847 and 1758. The fires of 1889 covered *ca.* 79% of the area; the 1847 and 1758 fires covered at least 52 and 51%, respectively. No major fires occurred in the area after 1908. Thus, very few new age classes have been added to the landscape since 1919, or about 55 yrs ago. Fires occurred at 1-9 yr intervals from 1837-1971, and were much wider before then, ranging from 1-36 yrs. There was a fire every year from 1894-1908. "Major fires" covered more than 1.2% (500 ha) of the study area, and occurred at longer intervals,

ranging from 1-27 yrs. These fires accounted for most of the area burned from 1665-1975.

Mean fire return interval (MFRI) is the average number of years between consecutive fires in a specified area. The MFRI for the study area was 4.4 yrs during the period of record 1665-1975. For the 248 yr period prior to fire suppression (1907), there were 46 fires with a MFRI of 5.5 yrs. Major fires had a MFRI of 8.4 yrs. Fires covering more than 50% of the study area had a MFRI of 65.5 with a range of 42-89 yrs.

Since no fires burned the entire study area, MFRI's on an areal and elevational basis were considered more realistic for future research and management purposes. For comparison, 16-50 ha blocks of vegetation were chosen from grassland-savanna, Douglas-fir, lodgepole pine and subalpine forest community types. MFRI was at least three times longer for any given block within a community type than the MFRI for the entire study area. Fire periodicity varied from block to block within community types but the differences were not significant at $P < 0.05$. The MFRI for lodgepole pine was 26.8, Douglas-fir 17.6, grassland-savanna 20.6 and Engelmann spruce-subalpine fir 74 yrs. No statistical differences were found between lodgepole pine, grassland-savanna and Douglas-fir. However, all three low-elevation community types had significantly shorter MFRI's than those of sub-alpine forests.

The number of fires varied between different parts of the study area but there was no significant differences between blocks within broadly defined community types. The number of fires for lodgepole pine, Douglas-fir and grassland-savanna were similar (8, 11,

9 respectively) and showed a marked difference from the number of fires for the subalpine forests (4), but none were significantly different from each other at $P < 0.05$. Fires significantly decreased in number from low to high elevations in the study area. The number of fires on N-NE slopes was smaller than on S-SW slopes, but the differences were not significant at $P < 0.05$. Insignificant differences may have been due to a small sample size of fires because very few fires were intense enough to burn into high elevational forests.

MFRI shortened from 16.5 yrs in the Pre-European Period (1665-*ca.* 1800) to 1.3 yrs during the Settlement Period (1892-1910). This increase in fires could have been related to increased human activity as well as to erasure of fire evidence with time. With fire suppression during the Park Period (1913-1975) MFRI increased to 4.4 yrs and only 0.004% of the area burned per year. There was no increase in the frequency of fire during the short Railroad Period (1909-1912). Although the Settlement Period experienced the lowest MFRI, most of the fires were small and total area burned per year was only 0.99%. Three percent of the area burned per year during the Presettlement Period (*ca.* 1830-1892) and 13 of 16 fires were of major extent. These fires accounted for an equivalent of 300% of the area burned during the period 1665-1975. There was no increase in fire periodicity during the Fur Trade Period (*ca.* 1800-*ca.* 1830). Despite a MFRI of 16.5 yrs and loss of fire-scar evidence with time, the total area burned per year for the Pre-European Period (0.69) was more than that in the Fur Trade Period (0.28) and almost equal to that of the Settlement Period (0.99).

Estimates of forest burned per year after 1830 have been obtained by separate workers for different regions in the Canadian

Rockies. They indicate that the frequency and areal extent of forest fires were similar throughout the region, in spite of the fact that the areas did not experience closely similar human-use patterns.

The area burned per year in the study area fluctuated erratically and was not well correlated with human-use patterns, especially the larger area burned per year before the arrival of the white man. Therefore, climate is believed to be the principal factor that controlled the frequency and extent of past fires.

Since no precipitation records exist for Jasper before 1918, below-average growth rates of trees in the Jasper townsite area were used as dendroclimatological indicators of major drought years or periods which might correspond to fire years. When all fires between 1700-1913 were plotted against below-mean precipitation periods, 76% of the fires and 92% of the total area burned were accounted for. The 1758, 1847 and 1889 fires occurred during pronounced droughts and accounted for 61% of the total area burned for the period of record. Only 8% of the area was covered by fires during above-mean precipitation periods.

A comparison of different fire history studies from Minnesota, Montana and Alberta showed many fire years in common. The years 1714, 1758, 1807, 1834, 1846, 1847, 1858, 1863, 1883, 1884, 1889, 1904, 1905 and 1908 appeared to have been major fire years in the northern Rocky Mountains. Fire years 1807, 1863, 1884 and 1904 were common on a subcontinental basis. It is suggested that these similarities were related to major atmospheric circulation anomalies associated with subcontinental drought, but further investigations should be initiated on past climate and fire behavior during individual fire years.

Since the probability of fire was greater during such below-mean precipitation periods, it was concluded that climate was *the* major environmental factor controlling the frequency and extent of past forest fires. Erratic human-use patterns associated with the study area and the good correlations between past climate and fire history suggest that white man alone should not be blamed for the extensive forest fires of the nineteenth century since he arrived at a time when conditions were more favorable for such fires.

It was concluded that most fires between 1665 and 1913 were of low to medium intensity although occasional medium to high intensity fires did occur. The basis of this conclusion was an integration of the following observations: (1) scarring but not killing of fire-susceptible tree species such as lodgepole pine; (2) multiple fire-scarred trees not restricted to natural fire breaks but scattered throughout the area; (3) low MFRI's; and (4) a complex mosaic of age structures on the landscape.

Even-aged stands resulted where fire was intense enough to destroy all above-ground elements within an area. Although not infrequent in the valley bottom, the larger even-aged elements were most common on upper slopes of the study area. Stands with two or more age classes resulted where fires of low-medium intensity were not hot enough to kill all of the former stand. Such fires removed parts of the stands, scarred occasional remnants and provided for the regeneration of new age classes. These complex age structures were most widespread in the valley bottoms and decreased with increasing elevation. Within the valley bottoms, the fire history was most complex in an area bounded by Pyramid Lake, Maligne Canyon and Jasper townsite. A

fine-scale patchwork of several age classes over short distances was characteristic of rugged terrain where fire responded to complex physiographic moisture regimes. Some stands of lodgepole pine and Douglas-fir contained scar dates but no regeneration attributable to that fire year and were evidence for low intensity surface fires. Areas containing no evidence for past fires were found at higher elevations, being especially prevalent on northerly and easterly slopes of Marmot, Pyramid and Signal Mountains.

Fire intensity was related to moisture regime, organic matter accumulation, and the change in these factors through plant succession and slope, aspect and elevation position. Two major plant/fuel successional sequences were recognized for the study area: high elevational forests and low elevational forests. Each was characterized by a distinct fire regime that corresponded to organic matter accumulation. Because organic matter decomposition was faster in warm-dry lower elevation sites, subsequent fires were less intense. Where the moisture regime was more mesic, more organic matter accumulated and fires burned more intensely when drought conditions prevailed. Even-aged forests were therefore more extensive at middle-high elevations where conditions were cooler and moister for longer periods of time, decomposition rates were slower, and a more highly flammable fuel accumulation resulted between fires. Less organic matter on south- and west-facing slopes carried subsequent fires of low-medium intensity that left many remnants. Conversely, north- and west-facing slopes were more intensely burned, but fires occurred on them less often.

The mid-life organic matter accumulation minimum is longer at lower elevations because of rapid decomposition rates, and therefore

these forests have a lower flammability for a longer period of time. The mid-life fuel minimum is shorter at higher elevations because removal of organic material is not as fast as that in lower elevational forests. At the present time, organic matter accumulation is declining from post-fire maximum fuel loading on the portion of the study area where stands are less than about 75 yrs old especially at lower elevations. To this extent the fire hazard is declining. However, organic matter and flammability are increasing on most of the area since most of the forested landscape originated more than 80 yrs ago.

It was concluded that weather and climate determined not only the rate of organic matter accumulation, and therefore the amount of fuel, but also whether the fuel at a particular place and time would burn once ignited. Whenever weather conditions were favorable and ignitions possible, fires occurred as frequently as organic matter accumulated in sufficient quantity to support combustion over the forest floor.

Major fires occurred in clusters of 4-5 yrs and were separated by 11-27 yr intervals ($\bar{x}$ = 17 yrs). Within each cluster, the size of successive fires tended to increase exponentially with time, terminating with very large fires such as 1758, 1847 and 1889. These irregular exponential curves were attributed to oscillations in past climate and in the accumulation of organic material with time.

Integration of the fire history data and plant/fuel succession lead to the conclusion that forests of the Jasper townsite study area will eventually burn again. The longer they are without fire, the more organic matter will accumulate, and the more severe fire will be during favorable weather conditions.

The present age structure and organic matter mosaic are not as heterogeneous and dramatic as in the past because of fire suppression. The cyclic fluctuation of past forest fires has been lost since 1910. As a result, organic material is accumulating faster than it is being consumed, and the age structure mosaic is becoming more homogeneous thus destroying the forest's own mechanism for controlling the severity of successive fires. Therefore, it is predicted that given the proper weather conditions and an ignition source, the study area around Jasper townsite will experience a fire or series of fires that may be larger and more catastrophic than any recorded during the period of record 1665 to 1913.

Continuation of Parks Canada policy of fire exclusion in the area may lead to the elimination of strong environmental selection pressures that have been responsible for the evolution of the forest environment. Although fire exclusion has not had serious repercussions up to this point, development of a well-planned program of fire prescription and control is needed to maintain disturbance phases of the stand maturation sequence so that a more viable environment will remain for future generations.

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Figure 12. Stand origin map of the Athabasca, Maligne and Miette River valleys around Jasper townsite, Jasper National Park.

STAND ORIGIN MAP[a] OF THE ATHABASCA RIVER VALLEY AROUND JASPER TOWNSITE, JASPER NATIONAL PARK, ALBERTA.

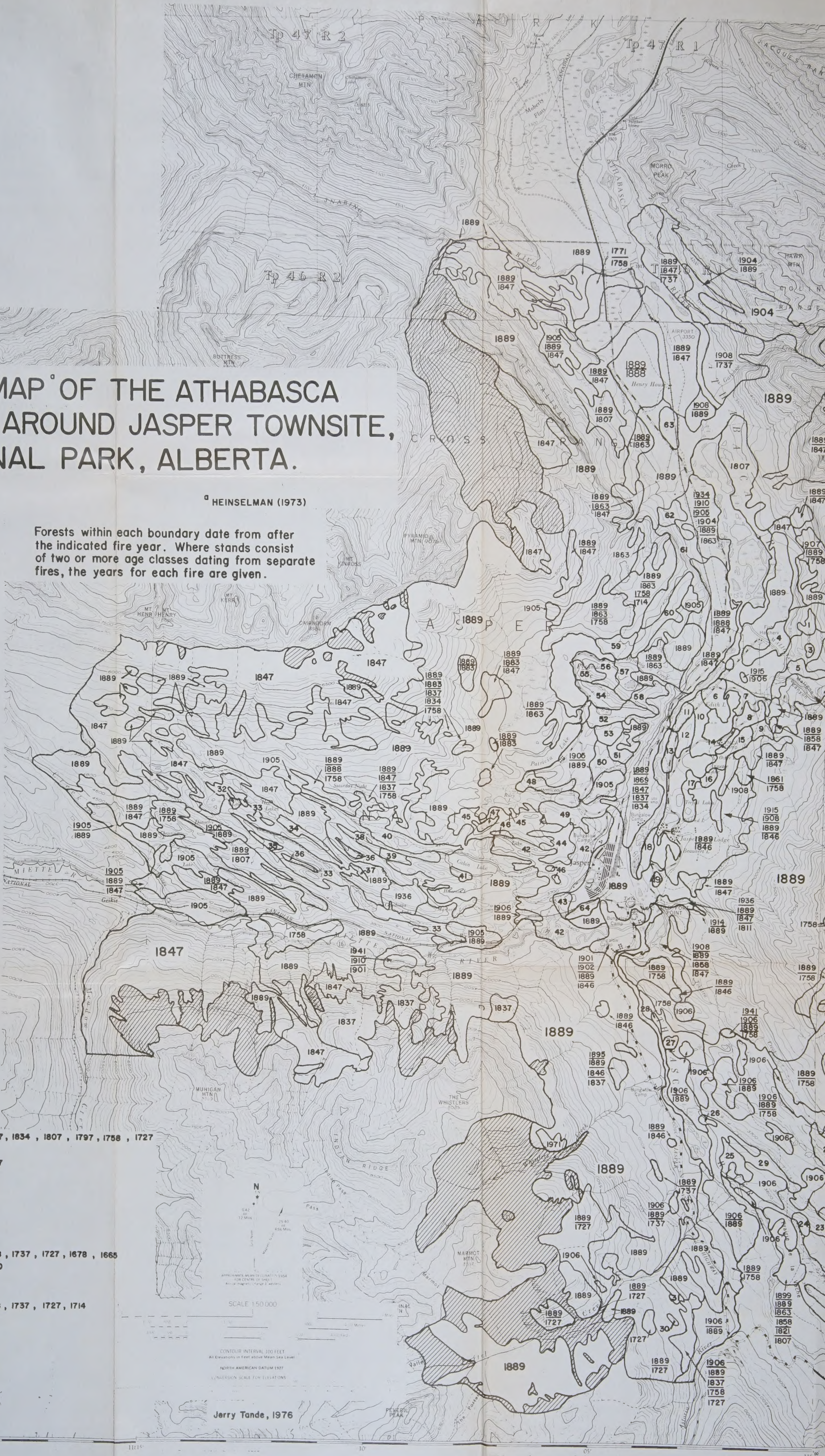
[a] HEINSELMAN (1973)

Forests within each boundary date from after the indicated fire year. Where stands consist of two or more age classes dating from separate fires, the years for each fire are given.

LEGEND

NO EVIDENCE FOR PAST FIRES

1. 1889, 1847
2. 1889, 1846
3. 1907, 1889, 1888
4. 1896, 1889, 1847, 1758
5. 1907, 1889, 1847
6. 1900, 1889, 1834
7. 1907, 1889
8. 1908, 1889, 1847
9. 1941, 1908, 1889, 1869, 1847, 1780, 1758, 1737
10. 1908, 1889
11. 1915, 1908, 1898, 1889, 1847, 1846, 1837
12. 1908, 1889, 1884, 1883, 1880, 1846, 1780, 1758
13. 1889, 1851, 1780, 1758
14. 1889, 1797
15. 1889, 1847
16. 1883, 1846, 1780
17. 1889, 1883, 1861, 1846
18. 1889, 1846
19. 1905, 1846, 1837
20. 1906, 1889, 1758, 1737
21. 1906, 1889, 1858, 1837, 1797, 1758
22. 1906, 1889, 1858
23. 1906, 1858, 1737
24. 1906, 1884
25. 1906, 1889, 1797
26. 1906, 1758
27. 1906, 1889, 1858, 1797
28. 1906, 1758
29. 1889, 1807
30. 1837, 1727
31. 1941, 1928, 1915, 1889, 1727
32. 1946
33. 1889, 1847
34. 1889, 1847, 1837, 1758
35. 1897
36. 1889
37. 1847
38. 1889, 1758
39. 1807
40. 1889, 1847
41. 1894, 1889, 1847
42. 1934, 1905, 1889, 1888, 1876, 1858, 1847, 1837, 1834, 1807, 1797, 1758, 1727
43. 1902, 1889
44. 1936, 1915, 1910, 1905, 1906, 1889, 1847, 1837
45. 1905, 1889, 1847, 1834, 1797, 1758
46. 1889
47. 1902, 1889
48. 1910, 1889, 1863, 1758
49. 1910, 1905, 1889, 1888, 1858, 1837, 1758
50. 1905, 1889, 1869, 1837, 1834
51. 1888, 1880, 1869, 1847, 1837, 1797, 1780, 1758, 1737, 1727, 1678, 1665
52. 1906, 1889, 1880, 1878, 1869, 1861, 1837, 1780
53. 1905, 1889, 1858
54. 1889, 1863, 1847, 1837, 1797
55. 1905, 1888, 1880, 1869, 1847, 1837, 1771, 1758, 1737, 1727, 1714
56. 1889, 1869, 1863
57. 1905, 1889, 1869, 1863, 1797
58. 1889, 1863, 1837
59. 1906, 1900, 1889, 1880, 1863, 1847
60. 1915, 1896, 1869, 1797, 1771
61. 1889, 1863, 1847
62. 1896, 1889, 1888, 1847
63. 1923, 1908, 1889, 1863
64. 1932, 1869, 1846, 1821, 1834



E ATHABASCA
ASPER TOWNSITE,
ALBERTA.
a HEINSELMAN (1973)
boundary date from after
ar. Where stands consist
classes dating from separate
each fire are given.
Jerry Tonde, 1976
SCALE 1:50 000
CONTOUR INTERVAL 100 FEET
NORTH AMERICAN DATUM 1927
Tp 47 R 2
Tp 47 R 1
Tp 46 R 2
CHETAMON MTN
MORRO PEAK
HAWK MTN
AIRPORT
ROCHE BONHOMME
GRISETTE MTN.
PYRAMID MTN
MT. KERR
CAIRNGORM
SIGNAL MTN.
Fire Lookout
EXCELSIOR MTN.
MT. TEKARRA
CENTRE MTN.
AMBER MTN.
THE WHISTLERS
MARMOT MTN
MUHIGAN MTN
PEVERIL PEAK
ATHABASCA RIVER
MALIGNE
COLIN RANGE
JASPER